WATER QUALITY STUDY OF WENATCHEE AND MIDDLE COLUMBIA RIVERS BEFORE DAM CONSTRUCTION

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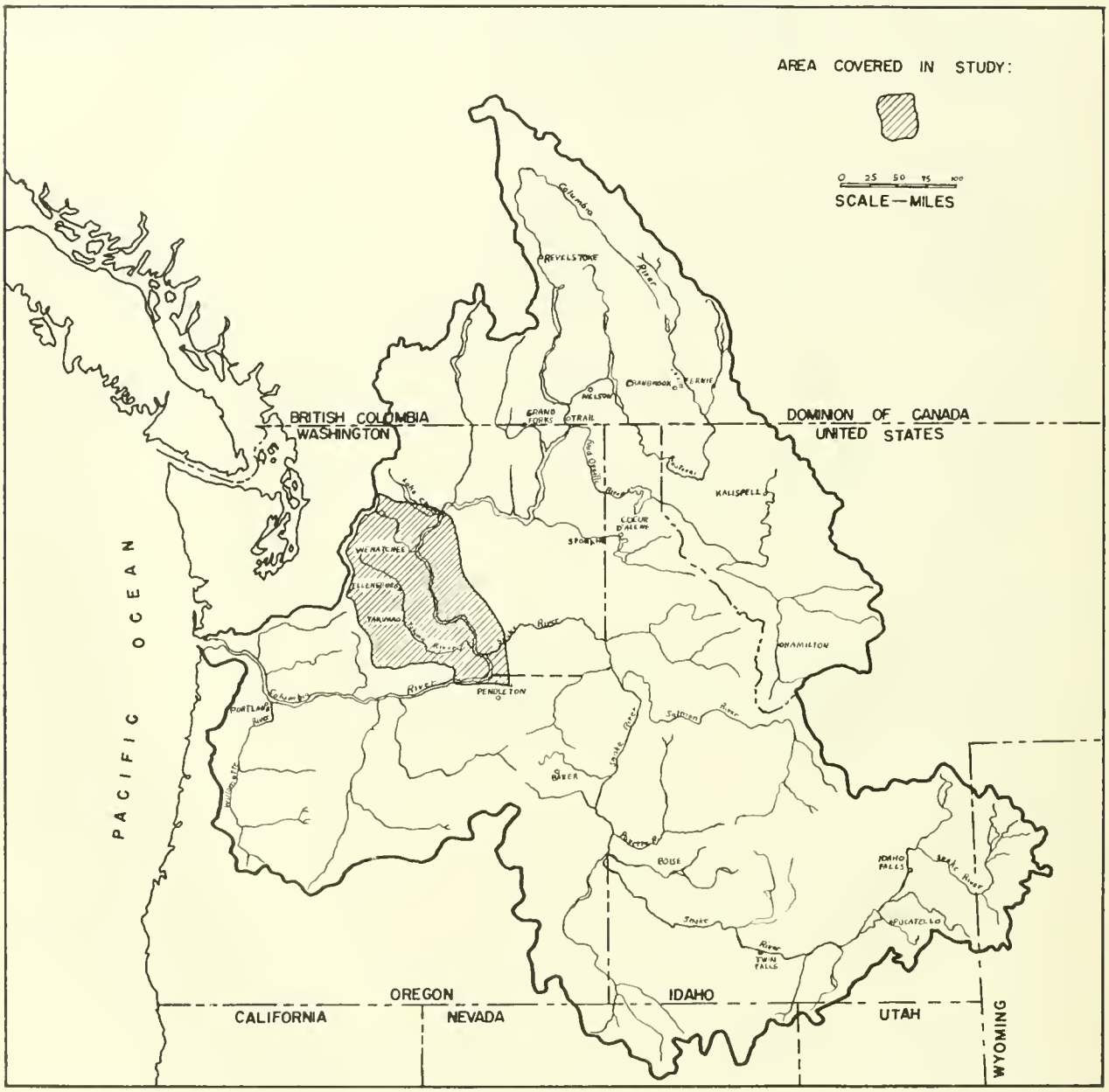


Figure 1.--Columbia River Basin, showing area covered in study.

WATER QUALITY STUDY OF WENATCHEE AND MIDDLE COLUMBIA RIVERS BEFORE DAM CONSTRUCTION

ABSTRACT

A water quality study was made in the Wenatchee River Basin and on the Columbia River from Beebe (near Chelan, Washington) to McNary Dam for the purpose of ascertaining the effect proposed dam construction will have on water quality and its relation to aquatic life. Water samples were collected during the period from June 1954 to April 1957. They were analyzed for the common constituents and for other constituents that might affect aquatic life. These data are summarized and discussed. They are compared with similar data collected in 1910-11.

INTRODUCTION

Public Utility District No. 1, of Chelan County, Washington, and Public Utility District No. 2, of Grant County, Washington, are developing hydroelectric facilities on the Columbia River. Federal Power Commission licenses for these facilities direct the sponsors to carry on project planning in cooperation with Federal and State agencies concerned with the fishery resource. The United States Fish and Wildlife Service, as a Federal agency, has worked with the Public Utility Districts in the planning of these power facilities so far as they might affect the fishery. This study has been supported by these Public Utility Districts through the U. S. Fish and Wildlife Service, which in turn contracted for the study through the University of Washington and its Department of Civil Engineering (1).

Existing and proposed dams in the vicinity of this study area are shown in figure 2 (page 2). The Chelan P.U.D. proposed (2) the construction of a power dam at Rocky Reach (now under construction) on the Columbia River 9 miles north of the City of Wenatchee. This P.U.D. operates the Rock Island Dam power development on the Columbia River 12 miles below Wenatchee. The Chelan P.U.D. has applied for a license from the Federal Power Commission to construct a dam on the Wenatchee River in the Tumwater Canyon area 35 river miles west of Wenatchee. This dam would divert water into a tunnel leading to a downstream powerhouse to be located near the City of Leavenworth. Studies for a power dam on the Chiwawa River have been deferred because of the high cost for a single-purpose project on this river.

The U. S. Corps of Engineers 308 Report of 1948 (3) proposed a single high dam at Priest Rapids on the Columbia River 68 miles downstream from Wenatchee. After this power site was acquired by the Grant County P.U.D. by action of Congress and by license from the Federal Power Commission, the P.U.D. decided (4) to erect two run-of-river dams to develop the power potential, rather than a single high dam. Cost comparisons and other factors led to the selection of this 2-dam scheme. The Priest Rapids Dam is now under construction and it is anticipated (4) that construction on the Wanspum Dam will commerce during 1958.

Table 1 (page 3) gives pertinent data on these dams and the other dams, existing or proposed, in the area included in this study (see fig. 2 for location). These dams are primarily for the production of hydroelectric power. They will have some multipurpose use however, in their navigation locks (when built) and in their (very small) flood control storage that can be made available by drawndown of the reservoir in advance of expected flood storage use. As shown in table 1, these are low head, run-of-river dams. They provide, at mean river flow, a theoretical water rentention period (not for flood control) in the reservoirs of only 0.25 to 4 days 1/. With completion of the proposed dams on the Columbia River, the river will be a series of lakes from Bonneville well into Canada, a distance of some 620 river miles.

1/ Rock Island has the lowest detention period of 0.25 days and Ice Harbor the greatest, or 4 days.

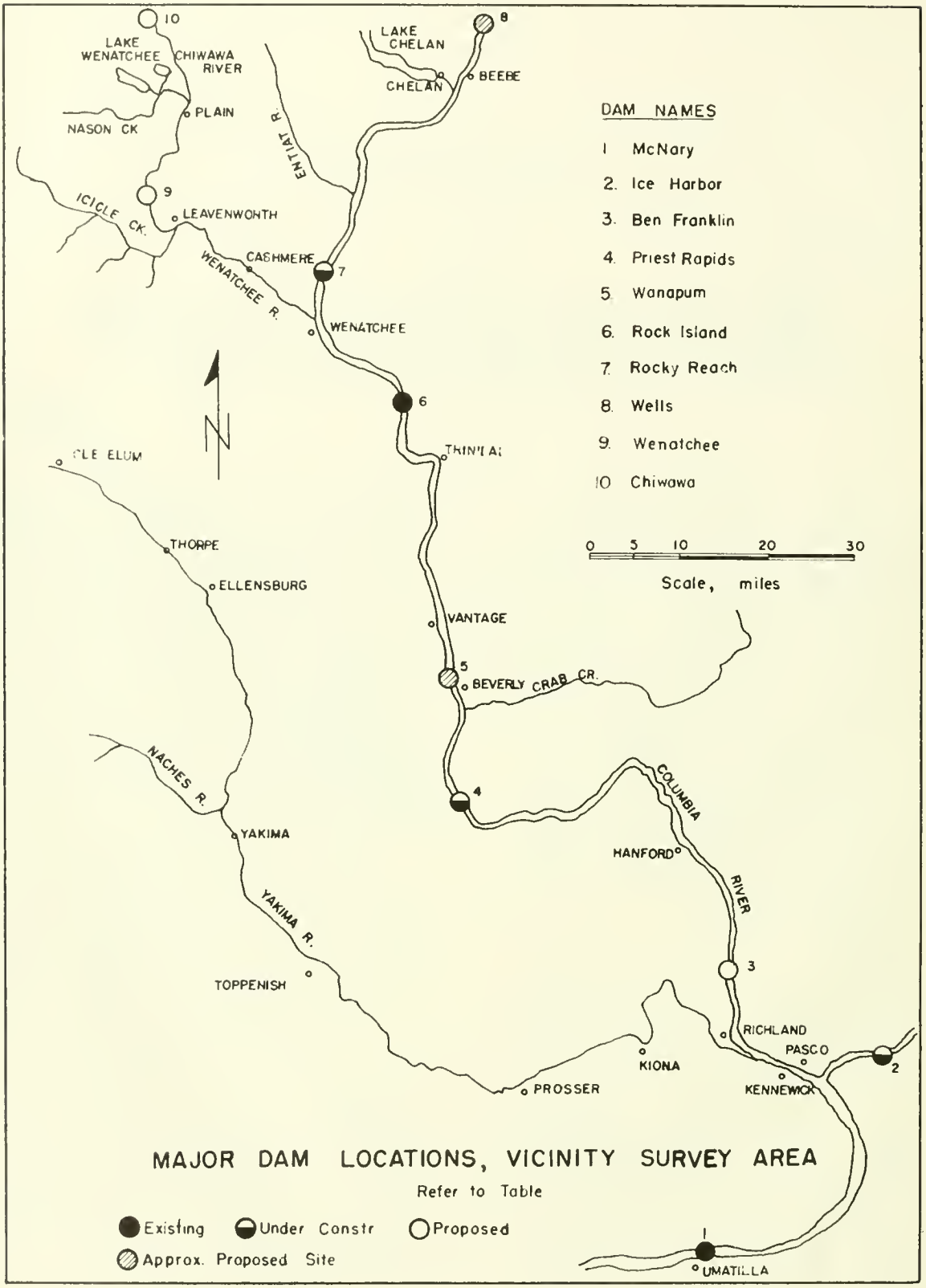

DAM NAMES
1 McNary
2. Ice Harbor
3. Ben Franklin
4. Priest Rapids
5. Wanapum
6. Rock Island
7. Rocky Reach
8. Wells
9. Wenatchee
10 Chiwawa
0 5 10 20 30
Scale, miles
LAKE WENATCHEE
CHIWAWA RIVER
NASON CK
PLAIN
ICICLE CK.
LEAVENWORTH
ENTIAT R.
LAKE CHELAN
CHELAN
BEEBE
CASHMERE
WENATCHEE R.
WENATCHEE
THORP
ELLENSBURG
VANTAGE
BEVERLY
CRAB CR.
NACHES R.
YAKIMA
YAKIMA R.
TOPPENISH
PROSSER
COLUMBIA RIVER
HANFORD
RICHLAND
PASCO
KIONA
KENNEWICK
UMATILLA
MAJOR DAM LOCATIONS, VICINITY SURVEY AREA
Refer to Table
Existing
Under Constr
Proposed
Approx. Proposed Site

FIG. 2

Table 1.--Dam and reservoir data, approximate values.

No.	Dam name	River miles to mouth Columbia River	Status	Reservoir surface area, average	Reservoir length	Average width reservoir	Usable storage	Dead storage	Water depth at dam	Average [4] head on turbine intakes
				Acres	Miles	Miles	Acre-feet	Acre-feet	Feet	Feet
1	McNary	292	Constructed	28,500	61	1.0	173,000	707,000	90	55
2	Ice Harbor	334	Under Constr.	7,000	35	0.4	29,000	388,000	100	70
3	Ben Franklin [1]	347	Proposed	---	49	---	---	---	---	--
4	Priest Rapids	397	Under Constr.	8,500	18	0.75	70,000	200,000	88	80
5	Wanapum [2]	415*	Proposed	13,500	38	0.55	85,000	520,000	115	75
6	Rock Island	453	Constructed	3,400	20	0.27	12,000	---	67	52
7	Rocky Reach	474	Under Constr.	9,300	42	0.35	47,000	---	110	97
8	Wells [1]	516	Proposed	6,800	29	0.36	---	---	79	--
9	Wenatchee [1]	500	Proposed	---	7	---	---	---	140	--
10	Chiwawa [3]	530	Proposed	---	--	---	120,000	---	179	--

* Site is tentative.

1/ Federal Power Commission permit or license has been requested.

2/ Construction expected to start in 1958.

3/ Not economical for single-purpose power usage.

4/ Vertical distance from average water surface to mid-depth of opening in dam face leading to turbine.

A discussion of existing and proposed facilities at these dams for the passage of migratory fish is beyond the scope of this study.

SCOPE OF THE STUDY

This study is specifically related to hydroelectric projects that have been proposed by the Chelan and Grant County Public Utility Districts on the Wenatchee and middle Columbia Rivers. Water quality and biological data have been collected, documented, and analyzed in the river sections that will be affected by these future dams. Biological data were gathered only in the Wenatchee River Basin. This report on the study is divided into two sections: a section on water quality, and a section on the biological studies 1/ in the Wenatchee River Basin. Some of the data included herein were obtained on a previous study (5) by the University of Washington for the U. S. Fish and Wildlife Service. This previous contract extended from June 1954 to December 1956, whereas the contract for the study reported herein extended from June 27, 1956, to September 15, 1957. Data collected by the U. S. Fish and Wildlife Service in 1939 and 1940 are included where applicable (24).

1/ Biological section not included.

Data sampling stations were selected to bracket the area; to lie near sites for the proposed dams; to include a riffle area if biological sampling was involved; to include a bridge, if possible, for ease and reliability of sampling; and to include tributary streams where water quality data would help explain quality changes in the main stream. The sampling stations, as listed in table 2, carry a station number assigned in the previous survey (5). Figures 3 - 6 (pages 5 - 8) show the locations of the University sampling stations and those of the U. S. Fish and Wildlife Service. Stations 16, 47, 23, and 42 were selected to bracket the study area on the Columbia and Wenatchee Rivers. Stations 13, 14, 17, 37, and 43 were selected as they would give water quality data relating to the primary stations that were located in the vicinity of the proposed dams. Station 38 (see fig. 3) is located between the Priest Rapids and Wanapum Dam sites. This is a difficult section of the Columbia River to sample because a bridge or boat was not available and because the shoreline depth and point of sampling will change with the change in river flow depth. Station 40 is located at the upstream end of the future Wanapum reservoir; station 44 several miles below the proposed Wenatchee reservoir; station 46 just below the proposed Wenatchee reservoir; and station 47 is located near

Table 2.--Location of sampling stations.

Station No.	Station	Miles from Columbia River mouth	Type of samples collected
13	Columbia River at McNary Dam	292	Water quality only
14	Snake River near mouth	326	" " "
16	Columbia River at Pasco	328	" " "
17	Yakima River near mouth	340	" " "
22	Yakima River near Thorp	493	" " "
23	Wenatchee River near mouth	471	Water quality and biological
37	Crab Creek near mouth	411	Water quality only
38	Columbia River above Priest Rapids	409	" " "
40	Columbia River at Rock Island Dam	453	" " "
41	Lake Wenatchee	528	Biological only
42	Lake Wenatchee	526	Water quality and biological
43	Nason Creek near mouth	523	" " " "
44	Chiwawa River near mouth	524	" " " "
45	Wenatchee River below Plain	514	" " " "
46	Wenatchee River in Tumwater Canyon	503	" " " "
47	Columbia River at Beebe	504	Water quality only

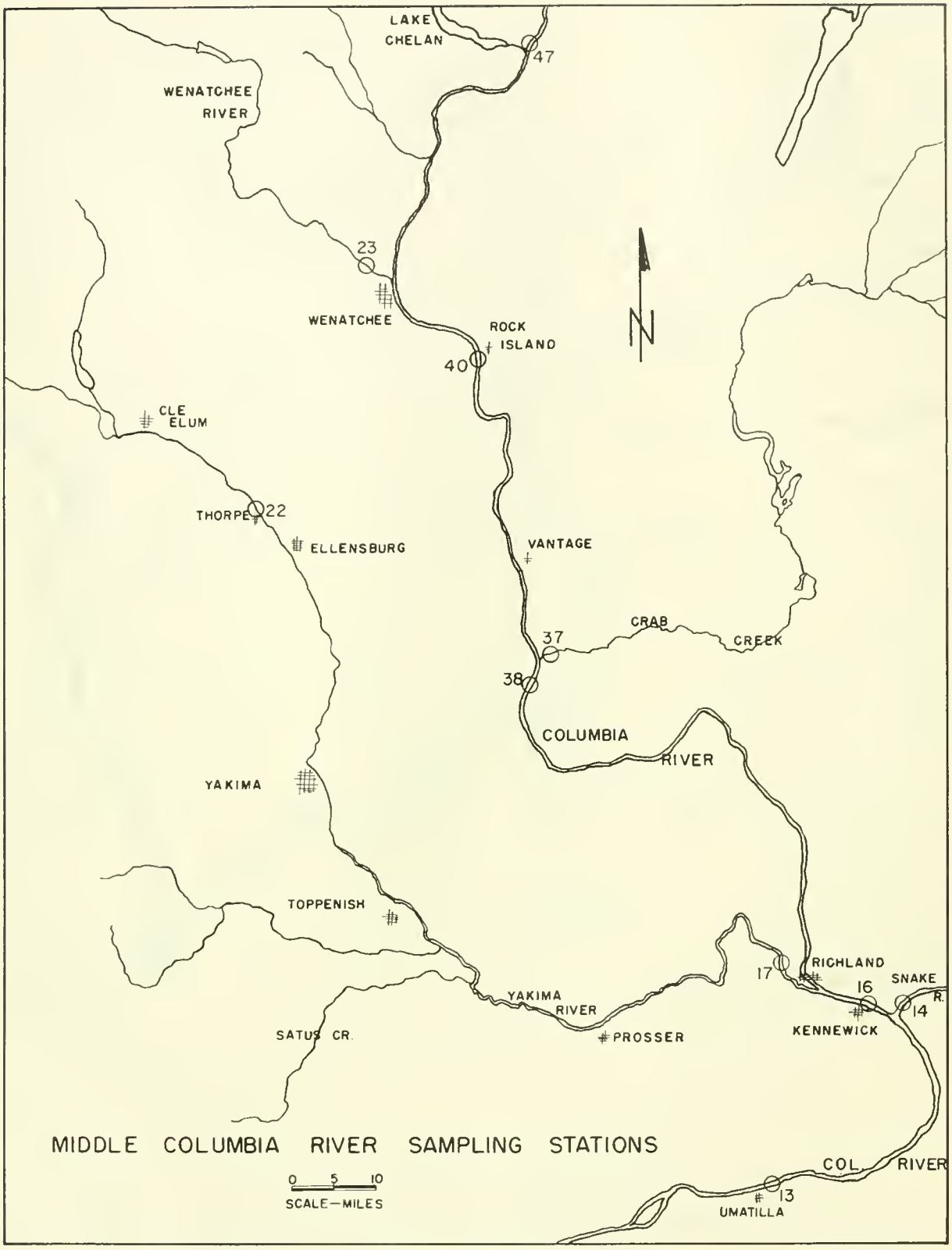

LAKE CHELAN
47
WENATCHEE RIVER
23
WENATCHEE
ROCK ISLAND
40
CLE ELUM
THORPE
22
ELLENSBURG
VANTAGE
CRAB CREEK
37
38
COLUMBIA RIVER
YAKIMA
TOPPENISH
SATUS CR.
YAKIMA RIVER
PROSSER
17
RICHLAND
16
SNAKE R.
14
KENNEWICK
COL. RIVER
13
UMATILLA
MIDDLE COLUMBIA RIVER SAMPLING STATIONS
0 5 10
SCALE—MILES

FIG. 3

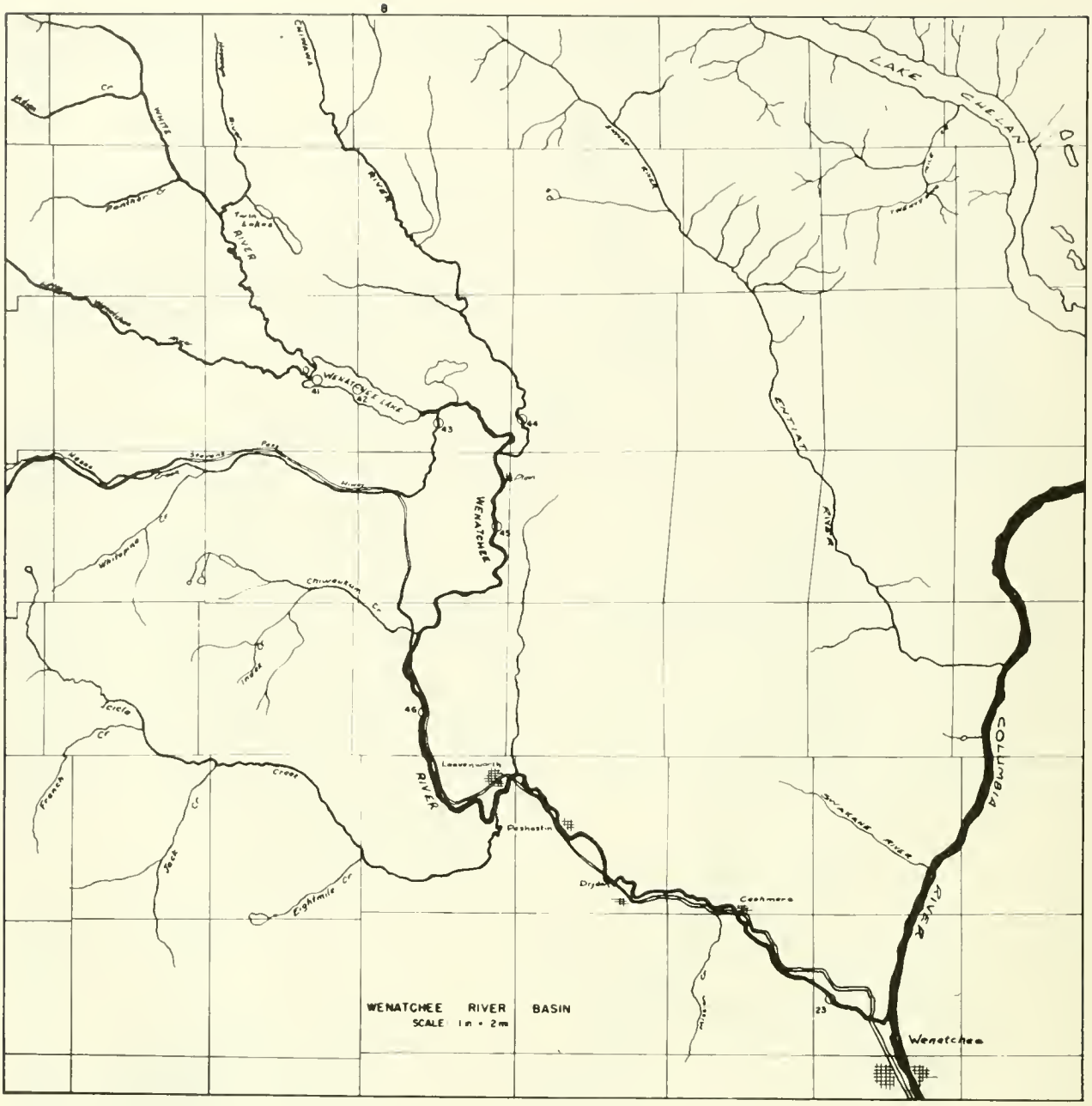

LAKE CHELAN
WHITE RIVER
Twin Lakes
WENATCHEE LAKE
WENATCHEE RIVER
ENTIAT RIVER
Chiwaukum Cr.
Icicle Cr.
French Cr.
Jack Cr.
Eightmile Cr.
Leavenworth
Peshastin
Dryden
Cashmere
SNAKANE RIVER
COLUMBIA RIVER
Wenatchee
WENATCHEE RIVER BASIN
SCALE 1 in = 2 m

FIG 4

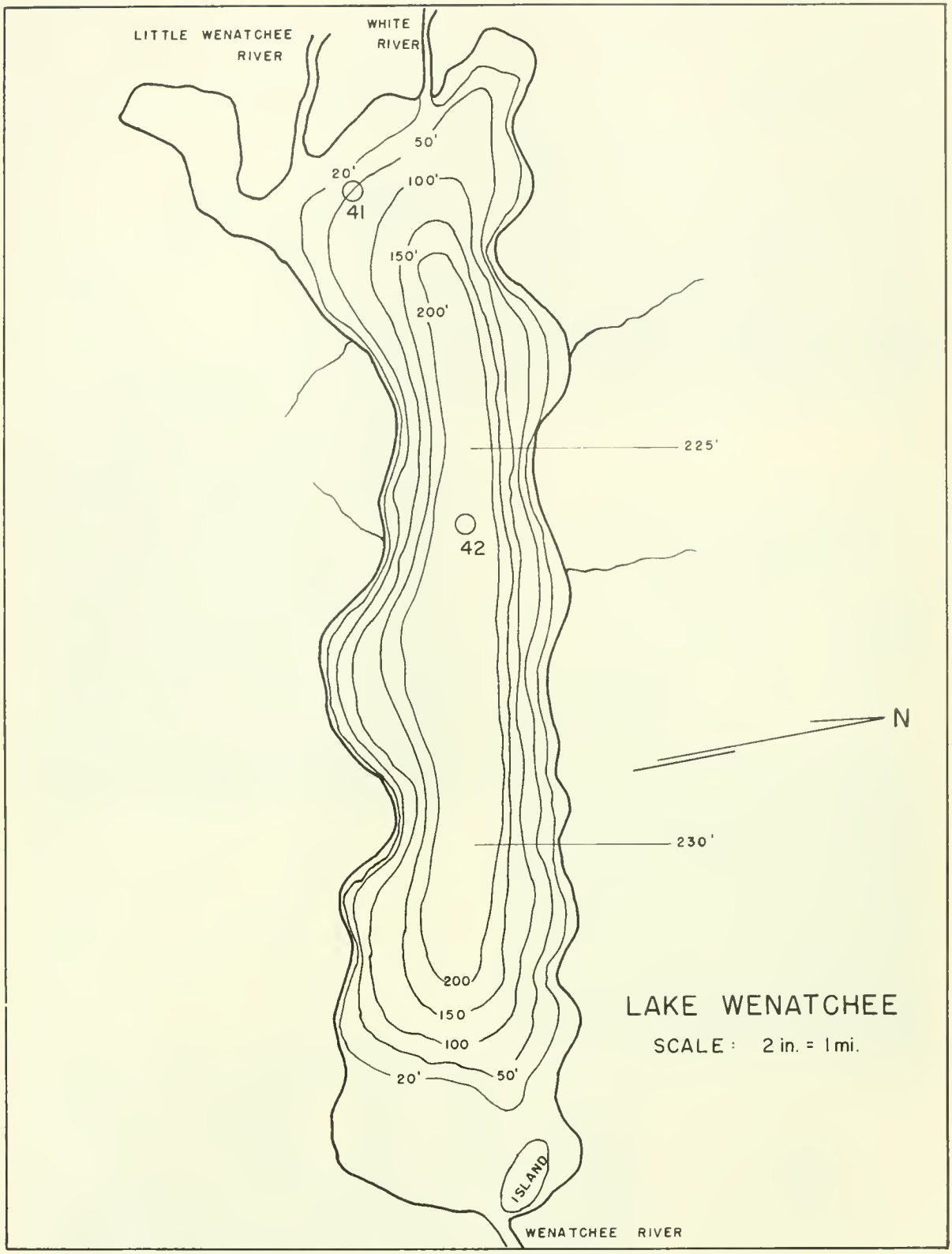

LITTLE WENATCHEE RIVER
WHITE RIVER
50'
20'
100'
41
150'
200'
225'
42
N
230'
200
150
100
20'
50'
ISLAND
WENATCHEE RIVER
LAKE WENATCHEE
SCALE: 2 in. = 1 mi.

FIG. 5

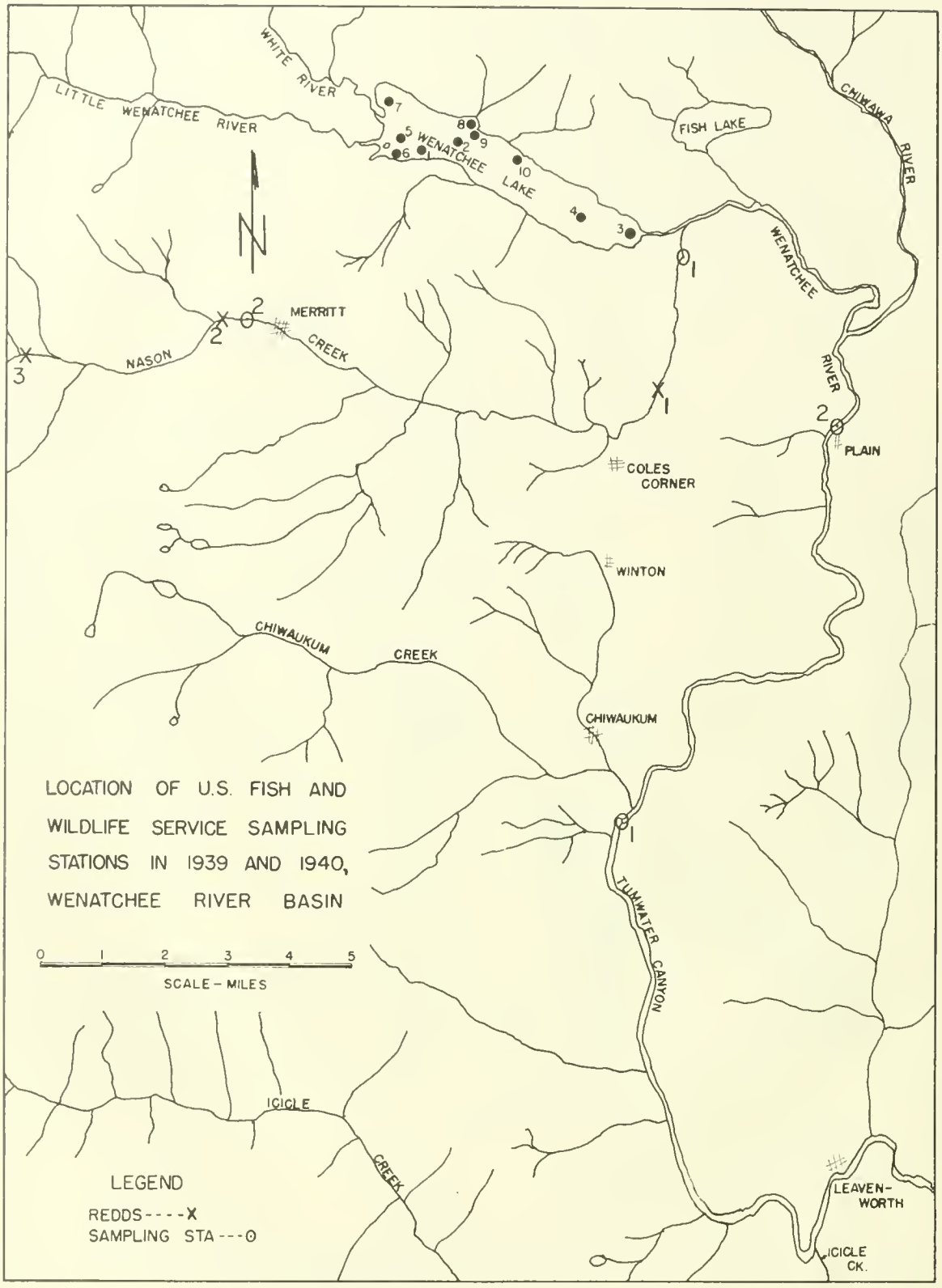
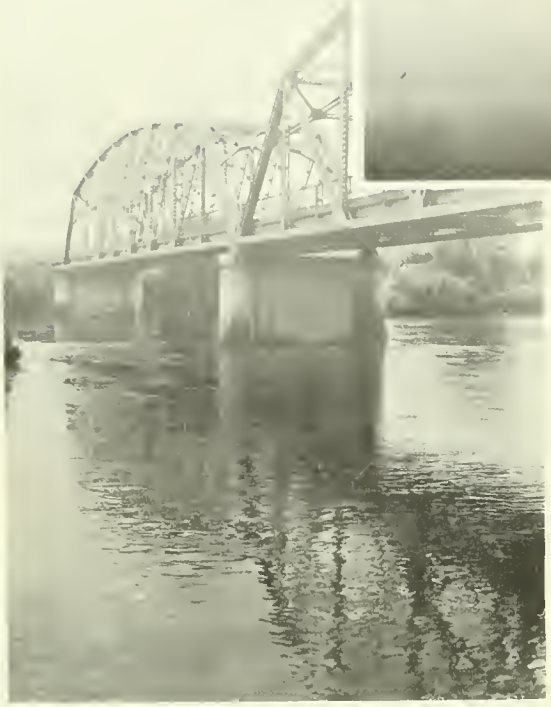

WHITE RIVER
LITTLE WENATCHEE RIVER
WENATCHEE LAKE
FISH LAKE
CHIWAWA RIVER
WENATCHEE RIVER
MERRITT
CREEK
NASON
COLES CORNER
PLAIN
WINTON
CHIWAUKUM CREEK
CHIWAUKUM
TUMWATER CANYON
ICICLE CREEK
LEAVEN-WORTH
ICICLE CK.
LOCATION OF U.S. FISH AND WILDLIFE SERVICE SAMPLING STATIONS IN 1939 AND 1940, WENATCHEE RIVER BASIN
0 1 2 3 4 5
SCALE - MILES
LEGEND
REDDS----X
SAMPLING STA---O

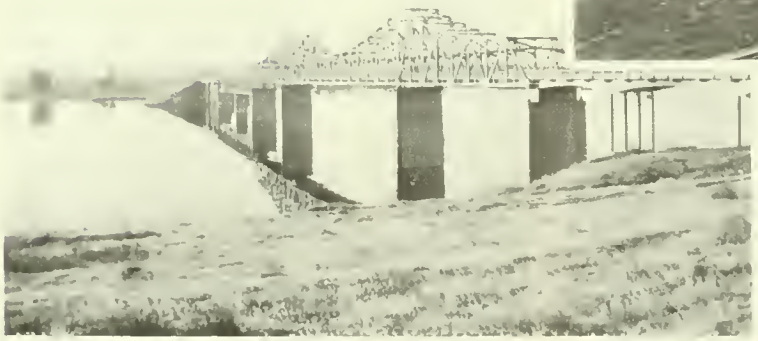
FIG. 6

STA. 16 - COLUMBIA RIVER AT PASCO



STA. 17 - YAKIMA RIVER AT ENTERPRISE

STA. 13 - COLUMBIA RIVER AT McNARY DAM



STA. 14 - SNAKE RIVER NEAR MOUTH

PLATE I

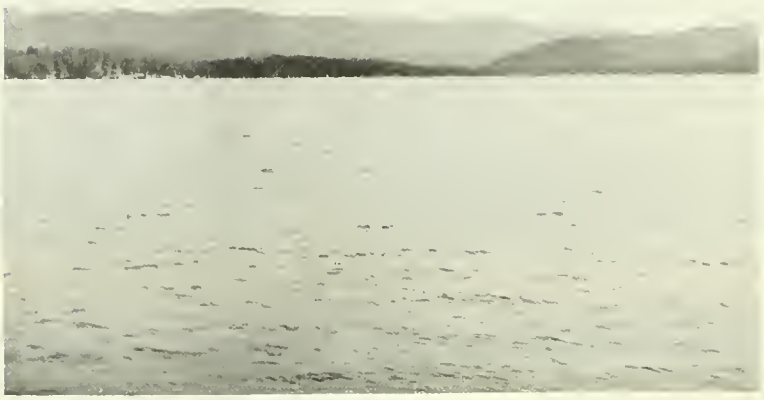
STA. 22 - YAKIMA RIVER ABOVE THORP

STA. 23 - WENATCHEE RIVER NEAR MOUTH

STA. 37 - CRAB CREEK NEAR MOUTH

STA. 38 - COLUMBIA RIVER AT VANTAGE

STA. 40 - COLUMBIA RIVER AT ROCK ISLAND



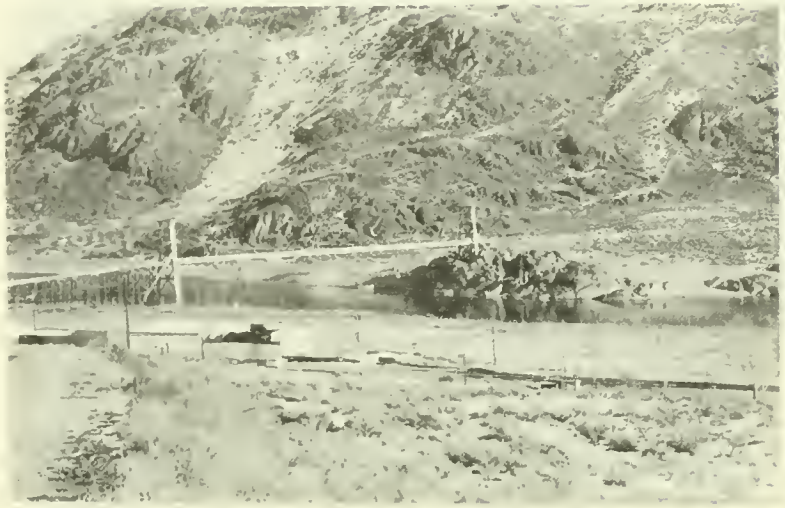
STA. 42 - LAKE WENATCHEE

STA. 43 - NASON CREEK NEAR MOUTH

STA. 44 - CHIWAWA RIVER NEAR MOUTH

STA. 45 - WENATCHEE RIVER AT PLAIN

STA. 46 - WENATCHEE RIVER AT TUMWATER CANYON



STA. 47 - COLUMBIA RIVER AT BEEBE ORCHARD

FIELD ANALYSIS

Rocky Reach Dam Construction

Priest Rapids Dam Construction

PLATE V

the upstream end of the future Rocky Reach reservoir. Station 22 on the upper Yakima River was sampled, since it was on the travel route of the sampling party and would thus give valuable information on a regulated stream with a minimum of cost and effort.

Plates I - V (pages 9 - 13) show these sampling stations and the initial construction work on the Rocky Reach and Priest Rapids Dams.

RIVER BASIN CHARACTERISTICS

Characteristics of the principal streams in the study area are given in table 3. Nason Creek has not been gaged sufficiently to permit an analysis of its flow characteristics. All streams have a very wide fluctuation in flow during a normal water year. Table 4 (page 16) gives the mean monthly discharge of the streams in the vicinity of the sampling stations during the period of the study. In a given month, the average monthly flow from year to year may vary by as much as 670 percent. These monthly flow variations and the yearly flow variations have a marked effect on the water quality and on the biota.

The yearly average flows during the study period were generally greater than the average flows of records, as shown in table 4. These higher flows may reduce the biota of the stream through scour and through a reduction in dissolved mineral matter concentrations.

Stream flow in 1939 and 1940 was considerably less than in 1954-57. The greatest stream discharge during the study period was in the 1956 calendar year.

Columbia River Basin

The principal river basin in the Pacific Northwest is the Columbia River Basin. This river system likewise has the greatest multipurpose water uses existing and proposed. It has supported very large runs of anadromous fishes, for whose continuation huge sums of money have been spent. This water quality study has confined itself within a small portion of the Columbia River Basin as shown in figure 1. There is a total of some 259,000 square miles in the drainage basin, of which 39,700 are in Canada. It includes most of the States of Washington, Idaho, and Oregon, the western part of Montana, and smaller areas in Nevada, Wyoming, and Utah, comprising about 7 percent of the nation's area.

The Columbia River has its headwaters in Columbia Lake, British Columbia, about 70 miles north of the international border at an elevation of 2,650 feet. After flowing 465 miles through Canada in a circuitous manner, the river enters the United States near the northeast corner of Washington. It flows through Washington in a series of big bends and becomes the border between Washington and Oregon as it flows westward to the Pacific Ocean. Between headwaters and the ocean, the river is some 1,200 miles long. Its annual average flow is around 160,000,000 acre-feet of water (or 220,000 cubic feet per second) that is discharged into the Pacific Ocean. The headwaters of the Columbia and its principal tributaries are in the mountains where precipitation is fairly high. Mountain snow packs produce ground storage plus seasonal peak flows in late spring.

The central portion of the Columbia, like its principal tributary, the Snake, lies in an arid region where irrigation is necessary for diversified farming. About 4,650,000 acres are now (1957) under irrigation (6) (7), two-thirds of which are in Southern Idaho. Ultimate development calls for a total of about 7,500,000 acres to be irrigated (8).

Because of its rapid fall from headwaters to the ocean, the Columbia and its tributaries offer many sites for hydroelectric power development. Despite the fact that there are now nearly 200 hydroelectric power developments in the Basin, only about 40 percent of the potential of over 10,000,000 kw. had been developed (8) as of 1947. (This figure has now increased to over 50 percent).

The U. S. Bureau of Reclamation in its report to the 81st Congress, "The Columbia River," 1947 (8), proposed construction of 238 projects, large and small, for irrigation, power, and flood control. The U. S. Corps of Engineers, North Pacific Division, in its "Review Report on Columbia River and Tributaries" ("308 Report"), 1948, (3), shows an ultimate development of

Table 3.--Stream characteristics.

Sampling station Sampling	River	Location	Drainage area square miles	River length above stations miles	Flow to 1954, c.f.s.		
					Minimum	Maximum	Average
47	Columbia	at Beebe Bridge	89,700(2)	695	34,800(12)	117,000	117,000
40	Columbia	at Rock Island	89,700(2)	746		692,600	117,000
38	Columbia	below Vantage	89,700(2)	790		692,600	117,000
16	Columbia	at Pasco	89,700(2)	869		692,600	117,000
13	Columbia	at McNary Dam	217,000	907	31,000	1,170,000	187,000(11)
43	Nason Creek	near mouth	---	19	--	---	---
44	Chiwawa	near mouth	170(3)	30	56	5,880	443
45	Wenatchee	below Plain	591	10	168	22,700	2,179
46	Wenatchee	Tumwater Canyon	591(4)	23	168	22,700	2,179
23	Wenatchee	Sleepy Hollow	1,000(5)	52	183	32,300	2,900
14	Snake	near mouth	103,200(6)	1,000	10,600	369,000	51,100(10)
37	Crab Creek	above Beverly	4,500(7)	145(1)	0	3,300	41
22	Yakima	near Thorp	1,590(8)	45	138	41,000	2,350
17	Yakima	near Richland	5,600(9)	195	105	67,000	3,170(10)
--	Icicle Creek	above Snow Creek	193	22	45	11,600	589

[1] Length indefinite
[2] At Trinidad
[3] 1936-1949
[4] At Plain
[5] At Peshastin
[6] Near Clarkston
[7] Near Smyrna
[8] At Umtanum
[9] At Kiona
[10] 1938-1952
[11] Adjusted from Dalles values
[12] Since Grand Coulee Dam Impoundment

Table 4 - Mean Monthly Discharge - C.F.S.

River Stations in Study Area

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY AVG.
Columbia River at Grand Coulee Dam, Wash. 1000 CFS													
1954	61.64	56.01	66.03	59.03	234.8	358.1	329.6	164.7	107.3	65.4	65.2	64.4	139.0
1955	63.1	72.2	70.8	71.52	75.32	290.7	300.2	133.7	78.5	62.4	65.8	63.0	112.9
1956	67.0	65.6	67.1	172.0	280.0	401.0	222.0	113.0	72.7	63.5	60.3	54.4	136.3
1957	71.4	64.3	50.8										-
Of Record[1]	48.5	47.1	51.7	86.8	210.3	290.9	200.1	109.2	69.6	56.2	51.3	49.8	100.3
Columbia River at Trinidad, Wash. 1000 CFS													
1954	68.15	62.8	72.51	66.76	247.0	387.3	359.1	178.9	117.3	72.7	74.4	71.7	148.1
1955	68.3	77.4	86.7	80.22	89.58	326.0	342.0	149.3	82.6	70.1	78.8	70.0	126.9
1956	74.3	73.2	74.5	184.0	323.0	450.0	251.0	120.0	80.2	72.3	70.6	66.4	153.1
1957	79.3	72.3	56.3										-
Of Record[1]	54.2	52.2	56.8	95.6	230.2	316.9	220.2	117.6	75.4	62.1	58.0	55.9	116.2
Columbia River at McNary Dam, Oregon 1000 CFS													
1954	106.0	116.0	123.7	151.9	373.0	487.0	413.0	210.0	149.0	105.6	108.0	97.3	203
1955	95.2	102.0	110.0	132.0	191.0	443.0	392.0	211.1	108.0	97.5	119.0	137.0	178.1
1956	132.0	118.0	152.0	329.0	521.0	627.0	298.0	153.0	110.0	103.0	103.0	100.0	229
1957	107.0	113.0	131.0										-
Of Record[1]	91.0	98.2	113.6	169.4	353.4	433.4	272.4	146.5	101.0	90.4	91.8	84.8	173.0

Table 4 - Cont'd

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY AVG.
Wenatchee River below Lake Wenatchee, C.F.S.													
1939	890	370	540	1,810	3,380	2,550	1,730	500	250	340	710	970	1,170
1940	380	420	820	1,950	3,390	2,300	760	340	270	515	400	530	1,010
1954	695	505	535	1,110	3,830	4,220	4,560	1,970	885	620	1,400	780	1,760
1955	425	495	325	645	2,040	5,140	3,340	1,220	470	970	2,040	745	1,490
1956	430	270	320	1,850	5,120	5,070	3,580	910	495	920	885	1,745	1,800
1957	540	435	565										-
Wenatchee River at Plain, C.F.S.													
1939	1,420	660	950	3,000	5,630	4,130	2,670	830	420	400	860	1,450	1,880
1940	640	680	1,330	3,320	5,520	3,850	1,260	720	400	810	615	830	1,660
1954	1,050	815	900	2,000	6,870	7,550	7,540	3,050	1,380	1,030	2,230	1,310	2,970
1955	770	850	630	1,200	3,950	9,440	5,730	1,970	790	1,590	3,320	1,380	2,630
1956	800	585	635	3,650	9,770	9,200	6,090	1,620	825	1,470	1,450	2,780	3,240
1957	955	775	1,005										-
Wenatchee River at Peshastin, C.F.S.													
1939	1,840	900	1,370	4,230	7,450	5,520	3,480	980	500	610	1,150	2,040	2,500
1940	880	920	1,860	4,400	7,770	5,210	1,590	660	540	1,045	780	1,070	2,230
1954	1,490	1,210	1,410	2,840	9,560	10,200	10,500	4,090	1,790	1,300	2,844	1,770	4,080
1955	1,021	1,100	880	1,700	5,305	13,320	7,717	2,420	950	1,820	3,920	2,080	3,520
1956	1,330	846	1,000	5,950	14,000	13,400	8,630	2,120	1,090	1,920	1,940	3,550	4,650
1957	1,260	960	1,410										-
Of Record[1]	1,210	1,190	1,453	3,910	8,420	8,230	3,920	1,190	730	1,210	1,530	1,890	2,890

Table 4 - Cont'd

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY AVG.
Chiwawa River near Plain, C.F.S.													
1939	150	100	150	600	1,270	970	620	210	110	110	130	210	386
1940	110	90	210	710	1,490	1,110	390	150	100	180	125	115	398
1954	-	-	-	-	-	-	-	-	300	240	420	280	-
1955	175	165	150	235	940	2,640	1,400	480	200	345	570	225	630
1956	150	95	105	765	2,680	2,400	1,440	420	220	230	205	325	752
1957	140	130	185										-
Nason Creek at Point of Discharge, C.F.S. [2/]													
1939	380	190	200	650	980	610	320	120	60	10	20	270	323
1940	150	170	300	600	640	380	110	230	30	115	90	185	250
1954	-	-	-	-	-	-	-	-	135	170	350	250	-
1955	170	190	155	320	970	1,000	930	270	120	275	710	410	515
1956	220	220	210	1,035	1,970	1,730	1,070	290	110	320	300	710	686
1957	275	210	255										-
Icicle Creek above Snow Creek, C.F.S.													
1954	245	205	250	495	2,020	2,240	2,290	765	335	200	515	325	828
1955	200	205	150	275	1,020	2,900	1,570	445	180	385	920	345	721
1956	205	160	160	1,015	2,800	2,655	1,010	385	210	335	330	755	886
1957	230	185	235										-
Crab Creek near Smyrna, Wash., C.F.S.													
1954	26	41	35	36	33	30	27	26	34	45	43	37	34
1955	39	38	33	35	32	21	24	30	36	51	40	50	36
1956	54	49	47	39	36	41	39	33	42	53	52	51	45
1957	37	64	56										-

Table 4 - Cont'd

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY AVG.
Yakima River at Cle Elum, Wash., C.F.S.													
1954	2,000	1,480	1,270	1,800	2,000	3,410	3,730	2,710	2,330	1,330	470	495	1,950
1955	450	665	595	1,750	1,520	4,580	3,140	3,000	2,430	895	1,890	3,000	2,000
1956	2,050	1,280	2,300	2,800	3,270	4,820	2,660	2,890	1,900	870	560	2,420	2,320
1957	1,275	370	460										
Yakima River at Kiona, Wash., C.F.S.													
1954	4,470	5,020	4,819	4,872	6,896	6,800	5,420	2,206	2,500	3,180	3,100	2,600	4,330
1955	2,190	2,430	1,850	2,000	3,249	8,720	3,525	1,809	2,050	2,900	6,140	9,360	3,840
1956	7,040	4,230	8,450	13,400	13,200	12,900	3,620	2,040	2,280	2,910	2,890	6,070	6,580
1957	3,530	2,800	4,000										-
Of Record[1]	2,940	3,380	4,000	4,450	5,530	3,530	2,010	1,610	1,750	2,260	2,860	3,710	3,160
Snake River near Clarkston, Wash., 1000 CFS													
1954	26.95	37.52	39.69	74.1	131.3	103.5	52.24	24.33	22.43	24.8	25.0	22.1	48.6
1955	22.0	20.8	23.2	51.8	99.74	128.6	51.52	21.55	20.6	24.4	30.7	53.2	45.6
1956	46.5	36.7	64.3	128.0	189.0	151.0	42.1	24.6	22.6	26.7	27.6	30.3	65.8
1957	23.4	35.8	66.8										
Of Record[1]	29.95	36.3	49.7	93.5	129.4	107.1	41.6	20.6	20.2	24.4	28.2	32.3	51.1

1 1938-52

2 Flow approximated by difference between Wenatchee River flows at Lake Wenatchee and Plain less Chiwawa River flow.

* Flow in Columbia, Yakima and Snake Rivers subject to regulation. Crab Creek flow is affected by irrigation usage and by irrigation surplus discharge.
1954-57 data from U.S.G.S. Provisional Records, subject to revision (9).

the Columbia River Basin that will provide a total of 125,000,000 acre-feet of storage [1/] on the river and its tributaries. This storage would make possible almost a complete regulation of the river system. To accomplish this, the Corps proposes the construction of 27 dams with an additional 131 dams, large and small, in the ultimate development.

Approximately 600,000 acres of land are now irrigated above Priest Rapids (5) in the Columbia River Basin and the future irrigated area may exceed 2,000,000 acres. Irrigation return flows from the Columbia Basin Projects' future annual diversion of 3,920,000 acre-feet (3) are estimated to be 233,000 acre-feet between Rock Island and Priest Rapids and 1,174,000 acre-feet in the vicinity of Pasco. The 1950 population in the Columbia River Basin above Priest Rapids was approximately 700,000 persons (5) (10) and the estimated future population is about 1,100,000 persons by the year 2000. This anticipated increase in irrigation and population with its concomitant increase in industry will produce future changes in Columbia River water quality.

Wenatchee River Basin

The Wenatchee River Basin is located entirely within Chelan County in north-central Washington, and it has an area of approximately 1,310 square miles (11). Originating in Lake Wenatchee, the Wenatchee River flows southeastward for 55 miles (12) to its confluence with the Columbia River immediately above the City of Wenatchee. It is an unregulated, rapid, snow-fed stream having a mean annual flow of 2900 c.f.s. and a fall of 1,230 feet from Lake Wenatchee to its confluence with the Columbia River (11). Principal tributaries below Lake Wenatchee are Nason Creek, the Chiwawa River and Icicle Creek (see fig. 4, page 6). Above Leavenworth, the river basin is mountainous and heavily forested. Below Leavenworth, the river enters a broader valley that is fully utilized for fruit growing (apples, cherries, apricots) and related enterprises, such as box factories, packing houses and storage plants. In 1950 the river basin above the City of Wenatchee had a population of some 12,000 persons, 3,270 of whom were in the Cities of Leavenworth and Cashmere (10).

Water diversion for irrigation commenced on a small scale about 1870 and continued until 1923, the last year of any significant irrigation development. There now exists 3,240 acres of irrigated land along the Wenatchee River above Peshastin and 25,470 acres above the river mouth (7). The estimated annual depletion in river discharge from irrigation usage is 50,940 acre-feet, which would correspond to a reduction in stream flow of 170 c.f.s. for an irrigation season of five months.

Lake Wenatchee, at the head of the Wenatchee River, is fed primarily by the Little Wenatchee and the White Rivers. Table 5 lists significant characteristics of the lake. The lake is very frequently subjected to the stirring action of strong winds blowing down from the adjacent mountain passes. It is normally frozen over during the winter months.

Table 5.--Lake Wenatchee characteristics

Area - square miles	4.4
Area - acres	2,820
Surface elevation - average	1,874
Maximum depth - feet	222
Average depth - feet	150
Volume - acre-feet	423,000
Shoreline length - miles	13
Drainage area - square miles	276
Maximum lake discharge - C.F.S.	13,700
Minimum lake discharge - C.F.S.	96

SOURCE OF POLLUTION

The Wenatchee River is relatively free of pollution. Significant sewage dicharges are treated prior to disposal in the river. Leavenworth has a modern sewage treatment plant providing secondary treatment to its waste waters and Cashmere has an outmoded sewage treatment plant providing primary treatment [2/] only. The minor industrial waste discharges to the river from the fruit industry plants are

1/ Storage for power, irrigation and flood control.

2/ Sedimentation.

in conformance with requirements of the Pollution Control Commission (14). Irrigation return flows are minor in the river basin. Assuming a net consumptive use of 2.0 acre-feet per acre (7) and an annual irrigation application of 4 acre-feet per acre, the return flow prorated over 12 months would be about 71 c.f.s. This amounts to 2.5 percent of the mean annual flow.

The Columbia River between Beebe Orchard Bridge and Priest Rapids receives very little polluting material in relation to the river volume. The City of Chelan discharges sewage to the Chelan River through a primary treament plant serving a population of 2,300 persons. Wenatchee and East Wenatchee discharge untreated sewage to the Columbia River from a connected population of about 14,000 persons (13). Sewage treatment is being planned for these cities. Other cities in the area do not discharge sewage to the river. All industrial waste discharges in the river section, including the aluminum and electro-metals plants at Malaga and Rock Island, meet the requirements of the Pollution Control Commission with the exception of a few food processing plants in Wenatchee. Irrigation return flows in this section of the Columbia River are small. Anticipated return flows of 233,000 acre-feet from the Columbia Basin Project will not be realized until the area is all under irrigation and not until the ground water table has been raised sufficiently to permit this return flow. A return flow of 233,000 acre-feet, prorated over 12 months, would be equivalent to a flow of 325 c.f.s. or 0.3 percent of the mean annual flow of the Columbia River at Trinidad.

WATER QUALITY CHANGES IN A RIVER

In a given river section, unaffected by man's activity, the quality of the river water is subject to change by natural causes as it flows through this section. The magnitude of the change will vary with the length of the section, depth of flow, shading afforded, elevation of the ground water table, turbulence and, it will vary with the physical and chemical characteristics of the ground over which the river flows. Tributary streams will of course have an effect on the water quality in the stream under consideration. Water quality changes that usually take place in a river section are as follows:

1. Increase in dissolved mineral matter and conductance.
2. Increase in water temperature during the summer months.
3. Decrease in water temperature during the winter if a large impoundment exists above the stream section.
4. Increase in pH if the area contains alkaline soil.
5. Color may be increased or reduced, depending upon the solar radiation received and on the nature of the surrounding soil.
6. Turbidity may be increased or reduced, depending upon the water velocity and the nature of the surrounding soil.
7. Dissolved gases, such as carbon dioxide, will decrease in a river section unless entrained organic matter is undergoing rapid decomposition. Dissolved oxygen will increase towards saturation or remain in a saturated state unless rapid decomposition removes oxygen faster than it is replenished by reaeration.

The natural water quality in a river is subject to change from 4 man-made causes. They are:

1. Impoundment of water in artificial reservoirs behind dams.
2. Return flows from irrigation.
3. Introduction of domestic sewage and industrial wastes.
4. Soil erosion or vegetative cover changes from farming, logging, or construction activities.

Impoundment of Water

The effect of water impoundment on water quality depends upon the time of impoundment, water depth, air temperatures,

character or reservoir bottom, whether highly organic or inorganic, on the physical and chemical quality of water entering the reservoir, wind action to provide circulatory currents, and on the point and depth of water withdrawal from the reservoir. Adverse water quality factors in regard to fish life that may arise from water impoundment are: High water temperature; low dissolved oxygen; high or low hydrogen ion (pH) concentration; excessive carbon dioxide, ammonia and hydrogen sulfide from organic decomposition, siltration, and, accumulation of trace elements that may be toxic to fish or their food supply, such as copper, lead, selenium, and zinc. Favorable water quality effects that may arise from impoundment are: a decrease in the downstream water temperature in the warm season and an increase in the winter; increase in downstream flow, during the normal low period, that will more effectively dilute pollutants, and a reduction in stream turbidity. Release of impounded water will affect the stream quality for some distance below the dam, depending upon the water turbulence, air temperatures, and the depth of water withdrawal from behind the dam. References (21-23) discuss the effects on water quality of impoundments in the Tennessee Valley Authority reservoirs and in the Catawba River, South Carolina.

Return Flows from Irrigation

In the irrigation of land, it is necessary that the soil be well-drained so that the plant roots do not become water sick and so that salts do not accumulate at the soil surface. A favorable salt balance is attained when the drainage water has a higher salt content than the input water (15). Most irrigation projects are provided with drains or waste-ways which control the direction of ground water movement in the root zone by returning excess ground and irrigation waters to a receiving stream.

The amount of water required for irrigation varies from less than two to more than 10 acre-feet of water applied per acre per year (16). Of this applied water, from 20 to 60 percent may find its way back to the stream as return flow.

These return flow waters are more mineralized and have different physical properties from the input waters. Their return to a stream will produce marked water quality changes if the quantity of return flow in relation to stream flow is significant. Some return flow can be expected throughout the year with the majority occurring at the height of the irrigation season.

Domestic Sewage and Industrial Wastes

The quantity of wastes discharged to to inland waters is continually increasing. Their content of polluting material is under surveillance by, and is in the process of being controlled by, water pollution control agencies. Uncontrolled discharge of these waste waters has, in many instances, caused serious impairment in water quality to the extent that fish life could not exist. It is to be expected that these waste waters will have an increased reduction in their deliterious effect on the receiving streams as waste treatment and other control processes become more common.

Soil Erosion

Poor land management practices, in the form of overgrazing or improper cultivation, together with logging, mining or construction activities that do not control soil erosion, frequently impart so much silt to a stream that all other forms of water quality impairment become minor in comparison. A change in vegetation, such as from coniferous to deciduous trees, will frequently result in an increase in the water color.

WATER QUALITY EFFECTS ON FISH LIFE

Water quality affects anadromous fishes in different ways. It may, if adverse, discourage the adults in their upstream migration; kill them by toxicity or disease before they reach the spawning grounds; cause them to not spawn when at the spawning beds; destroy their eggs by providing an environment unfavorable for hatching; or it may cause the newly hatched fish to die through destruction of the young fish itself or its food supply. A search of the literature for specific water quality constituents and their effect on anadromous fishes is not very enlightening. Different species of fish and the same fish

at different ages have varying tolerances to water constituents. The effect of a particular constituent also frequently depends upon the variation in concentration of other constituents.

A concise statement on the nature of the research and of the available data on toxicity to fishes is given in the California "Water Quality Criteria" (17). It reads as follows: "Not only are the references dealing with fish innumerable; they are also individualistic in their approaches to the problem. The conditions under which the numerous investigators conducted their experiment varied widely and were seldom standardized. Hence, the results of several investigators of the same pollutant may not compare closely. This wide discrepance arises from variations in the species of fish or other organism used, its prior handling, the temperature, the dissolved oxygen content, synergistic and antogonistic substances, the hardness and other mineral content of the water, and the time of exposure."

There is a dearth of specific information on water quality and fish life, and a need for more study on this subject. It was decided to make water tests for only those constituents regarded as harmful to fish life and to make other tests which would be helpful in general water quality evaluation. A study of this nature can concern itself only with those substances which are likely to be present. The reader is referred to reference (5) for a more complete discussion of toxicity of the various elements and compounds.

FIELD SAMPLING AND ANALYTICAL PROCEDURES

Sampling procedures were developed to obtain as nearly a representative sample as possible from the station to be sampled. The procedure had to be within the limitations of time, personnel, and equipment available. There was good vertical mixing at all of the stations as determined by temperature and water quality checks at the stations. In the smaller streams no significant difference in water quality could be found within the cross-section. In the larger streams, there was occasionally a slight change in water quality across the cross-section because of insufficient horizontal mixing below a tributary. Two or three samples were collected at about mid-depth across the cross-section of the stream on each visit. Three samples were collected from the large streams and two from the small streams. The water quality values reported are an average of the constituent values found on each visit. Sampling stations were visited from 2 to 4 times during the summer months and less frequently during the remainder of the year.

The water sampler most frequently used was a 1200 ml. improved-type Kemmerer sampler. This sampler is lowered in open position to the desired depth (in a lake or where the stream flow is not rapid) and then a messenger is sent down the attached line. This messenger trips a set of holding forks and rubber stoppers move in to seal the cylinder of water within the sampler. Sample bottles are carefully filled from the sampler by use of a rubber tube at the sampler base. Sample bottles used were the regular A.P.H.A. B.O.D. bottles, having a ground glass tapered stopper and holding about 300 ml. A weighted, displacement type, sampler was used where the current was swift or where the water was shallow. This sampler holds three B.O.D. bottles. During filling, to insure a representative sample, the contents of the bottles are displaced 3 times into the outer container. This type of sampler begins to fill immediately on lowering and is therefore not suited for deep reservoir or lake samples.

Water quality determinations were made: (a) in the field at, or shortly after the time of sampling, for those qualities whose value would change on standing; (b) in the laboratory within a day or two following sampling for those determinations not greatly affected by standing or where field testing would be most difficult; and (c) by a private testing laboratory for element analysis. All analyses were in accordance with "Standard Methods" (19) unless otherwise noted below.

Determinations made in the field and the analytical procedure used were as follows:

a. Temperature - a centigrade thermometer, reading to 0.1° C., was dipped in the water when possible. If not, a portable resistance

thermometer was used, reading to about 0.1° F., which could be lowered to any desired depth for a temperature reading.

b. pH - these values were generally measured electrometrically, using glass and saturated calomel electrodes standardized against a buffer solution. Colorimetric pH determinations were made, using a glass disc color comparator when an electrometric unit was judged unreliable (following a trip over rough roads) and as a check on the electrometric measurement.

c. Dissolved oxygen - samples were dosed at the time of collection with reagents for the sodium azide (Alsterberg) modification of the Winkler method. The percentage of saturation was computed using sea level saturation values at the temperature of sample collection. The percentage of saturation values were not corrected for the altitude of sample collection, i.e., barometric pressure.

d. Carbon dioxide - total carbon dioxide was approximated by adding 0.02 N NaOH to the phenolphthalein endpoint in a carefully collected sample.

e. Ammonia - sample was preserved with 0.8 ml. of concentrated H_2SO_4 per liter of sample at time of collection.

f. Alkalinity - total bicarbonate and carbonate (if present) alkalinity were determined by titration with 0.02 N H_2SO_4 against the phenolphthalein and methyl orange endpoints.

g. Hardness - total hardness was measured by titration using the Schwarzenbach method. Carbonate and non-carbonate hardness were calculated, using the total hardness--total alkalinity relationship.

Determinations made on samples brought back to the laboratory and the analytical procedures used were as follows:

a. Color - "Aqua Tester" was used to measure color by comparison with a glass disc calibrated against platinum-cobalt standards. Excessive turbidity was removed by centrifuging when necessary.

b. Turbidity - A Hellige turbidimeter was used to measure low turbidities. If turbidity values exceeded 30, the sample was diluted with distilled water. The turbidimeter was calibrated against a Jackson candle turbidimeter.

c. Conductivity - specific conductance was measured using a Wheatstone bridge and a specific conductance cell, calibrated against a standard KCl solution. Values were recorded in micromhos/cm., corrected to 25° C.

d. Ammonia - determinations were made by direct nesslerization in nessler tubes, and color readings were made by comparison with permanent standards, or from an electrophotometer calibrated against permanent standards. Precipitated interfering substances were removed by filtration or by centrifugation.

e. Sulfates - turbidimetric method was used by precipitating the sulfate ion with the barium ion in acid solution. Turbidity values, converted to p.p.m. of sulfate ion, were read from a Hellige turbidimeter calibrated against standard sulfate solutions.

f. Total solids - 100 ml. of sample was evaporated to dryness over a water bath, dried for at least one hour at 103° C., and weighed. Total solids and dissolved solids will have about the same value for nearly all stations where turbidities were low.

Samples for element analysis were periodically sent to a commercial laboratory set up for this type of analytical

work. The elements they tested for and the methods used were as follows:

a. Iron - Thiocyanate method, reference (19), 9th Edition.

b. Copper - Carbonate procedure, reference (19).

c. Zinc - "Colorimetric Determinations of Traces of Metals" by E. B. Sandell, p. 458.

d. Aluminum - reference (19), 9th Edition, p. 50.

e. Calcium - flame photometer against standards.

f. Magnesium - reference (19), titan yellow.

g. Sodium - flame photometer.

h. Potassium - flame photometer.

i. Lead - Sandell dithizone method (modified).

j. Manganese - reference (19), periodate method.

k. Silver - Sandell, dithizonate method, p. 400.

RELIABILITY OF WATER QUALITY DATA

The water quality of a stream is continuously changing. In a given stream, the value of the constituent tested for will vary with the rate of stream flow, with the water use and with the air temperature or season of the year. To obtain a reliable documentation of the water quality, one has the problem of determining how many and how frequently water samples should be collected. In their 12 established sampling stations in the Columbia River Basin, the U. S. Geological Survey normally collects a water sample each day. These samples for three 10-day periods are composited in ratio with each sample's conductivity. Thus, three constituent values are determined during each month of sampling. Even with these numerous samples, there are abrupt changes at some stations in the constituent values. The most accurate procedure would be the daily analysis of each sample. This becomes a virtual impossibility when the number of samples and constituents tested for are large. Collection of daily samples by a local resident of the area is a good and an inexpensive way to get numerous samples. It has the disadvantage of not permitting a test for dissolved gases, ammonia, phosphates, etc. and the samples have been stored for a considerable period prior to analysis which will affect pH, alkalinity, turbidity, nitrate and solids values.

On this contract, because of the large number of sampling stations involved, because of the necessity of measuring dissolved oxygen *et cetera* at each station, and because of a limited budget, it was not possible to get frequent samples at each station. Stations were sampled (composites at each station of two or more individual samples) with a frequency of at least once a month in the winter and up to 10 times in the summer months.

Hydrogen Ion Concentration (pH)

These values were measured in the field at the time of sampling with colorimetric indicators and also with a portable, battery operated, glass electrode pH meter. The glass electrode method usually gave pH values from 0-0.4 units higher than those given by the colorimetric method. Colorimetric values would differ by 0-0.2 units, depending upon the indicator used.

All of these pH values are at best, approximations, for the following reasons:

1. Colorimetric methods are subject to error from color perception of the observer, deterioration of the standards or the indicator and from pH alterations by the indicator in poorly buffered samples of water (19).

2. Electrometric methods are affected by temperature of the sample. As the sample warms, the pH will rise because of an increase in ionization in the sample and because of the nature of the electrodes themselves. This change in temperature was compensated for with the meters used when the water temperature was well above 10° C. When the water temperatures were

around 10° C. or lower the pH readings would be low. Thus, if a sample warmed from 10° C. to 20° C. from the time of sampling to the time of pH measurement, the pH read would be above that actually existing in the river. Electrometric pH values should be recorded with the sample temperature at the time of pH measurement.

Dissolved Oxygen

Recent laboratory studies in England by Truesdale, et al. (18) have shown the presently accepted (see reference 19) dissolved oxygen saturation values at sea level to be in error by as much as 4 percent. The present values are high according to these researchers (see below).

Temperature	Percent error in present values (high)
0° C	3.4
5	3.5
10	3.5
15	4.0
20	3.8
25	3.3
30	1.3

This report on the error in oxygen solubility confirms field data where, in many instances, a clean, turbulent river would have an oxygen saturation of 96-97 percent according to the old oxygen saturation values. A stream of this type should be essentially 100 percent saturated with oxygen. Therefore, all dissolved oxygen saturation values shown in this report should be about 3.5 percent higher. If the saturation values were corrected for elevation of the sampling station (barometric pressure), the values would be increased from about 4 percent for the Columbia River at McNary Dam to about 6 percent for Nason Creek.

Station 38, Columbia River Below Vantage

This sampling station was along the river bank at a location where the depth sampler could be immersed in several feet of water. Depth of sampler immersion along the bank varied from 3-15 feet, depending upon the river stage. Crab Creek discharges to the Columbia River about 1 mile above the sampling station. This distance may be insufficient for mixing during low river stages. These circumstances undoubtedly gave some values that were too high for temperature, alkalinity, hardness, sulfates, sodium and conductivity.

Ammonia and Carbon Dioxide

Values for these constituents are approximate only, as the test techniques used were not precise and because it was necessary to make the ammonia analysis 1 to 3 days after the samples were collected. Ammonia samples were preserved with sulfuric acid when collected and refrigerated when placed in the laboratory.

PRESENTATION OF WATER QUALITY DATA

An important portion of this study is the documentation of water quality prior to dam construction. Average-monthly constituent values observed at the river stations during the period of June 1954 through March 1957 are given in tables 6-20. Figures 7-34 are plots of these constituent values. Table 16 (page 27) summarizes the water quality data observed in Nason Creek by the U. S. Fish and Wildlife Service in 1940. Table 21 (page 70) presents water quality data obtained with depth in Lake Wenatchee from June 1955 to February 1957 while table 22 (page 76) presents similar data collected by the U. S. Fish and Wildlife Service in 1939. Since average constituent values (as given in tables 6-20) do not indicate the range in values actually observed, these ranges are given in table 23 (page 78) from minimum to maximum observed values. This table also gives the weighted-average constituent values for the entire period of observation. Weighted-average values take into consideration the diluting or concentrating effect produced by differences in stream discharge and they are obtained by multiplying each constituent value by the flow at the time of sampling, getting the summation of these products and dividing by the total flow in the period of summation.

Average-monthly water temperatures from thermograph stations in the study area are given in table 24 (page 86) together with minimum and maximum values and diurnal

Table 6.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

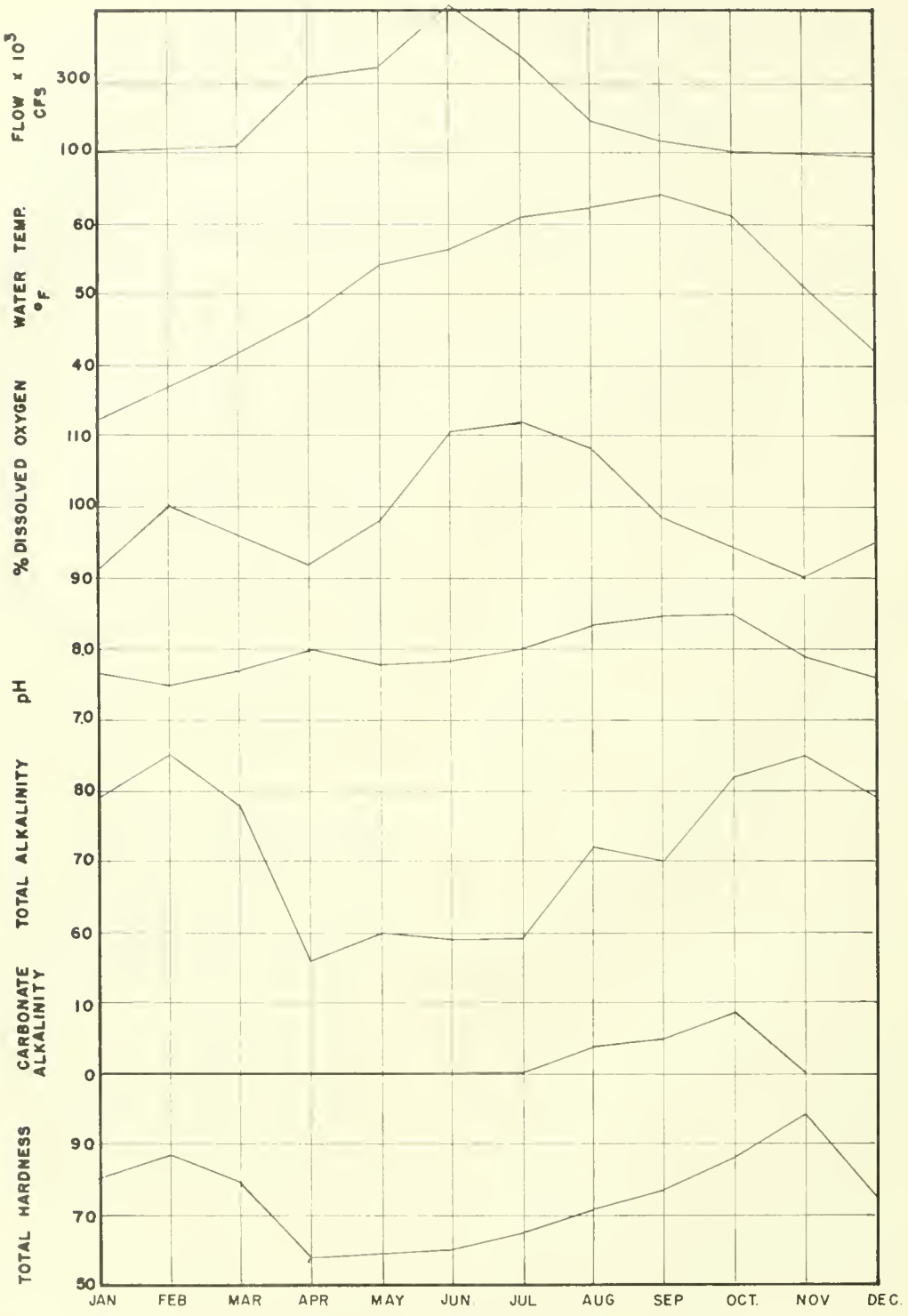
Sta: Columbia R. at McNary Dam Sta. No.: 13 Designation: C-292.0

Summary Period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	1,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	1	2	2	8	10	7	2	2	2
CFS 10^3	108	109	120	322	343	517	379	195	136	104	100	88
Water °F	32.4	37	41.9	47	54.3	56.5	61	62.24	64.1	61.1	51.1	42
Air °F 5	18.8	36.2	47.8	55.3	61.0	65.2	73.2	71.5	65.2	52.7	42.3	35.0
Dis. Oxy.	13.2	13.5	12.15	11.0	10.55	11.55	11.15	10.25	9.45	9.3	10.1	12
% Satur.	91	100	96	92	98.0	110.5	112	108.2	98.4	94	90	95
Car. Di.	0.8	2.0	1.8	1.5	1.3	1.0	0.6	0.1	0.1	0	0.5	1.2
pH	7.7	7.5	7.7	8.0	7.8	7.83	8.0	8.34	8.46	8.5	7.9	7.6
Ammonia	T	T	0.02	0.25	0.12	T	0.19	T	T	T	T	0.01
Total Alk	79	85	78	56	60	59	59	72	70	82	85	79
HCO_3-	79	85	78	56	60	59	59	68	65	73	85	79
CO_3-	0	0	0	0	0	0	0	4	5	9	0	0
Tot. Hard	81	87	80	58	59	60	65	72	77	86	98	75
Car Hard.	79	85	78	56	59	59	59	72	70	82	85	75
N. C. H.	2	2	2	2	0	1	6	0	7	4	13	0
Sulfates	27	23	20	13	12	13	12	15	16	23	20	16
Color	10	15	35	30	22	20	11	10	10	12	4	16
Turbid.	13	32	65	25	17	20	12	11	9	20	8	19
Iron	0.01	0.06	0.15	--	0.05	0.06	0.02	0.19	0.19	0.01	0.00	0.15
Copper	0.20	0.000	0.050	--	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
Zinc	--	--	0.0	--	00	--	--	--	0.0	--	--	0.0
Lead	--	--	0.0	--	0.0	--	--	--	0.0	--	--	0.0
Aluminum	0.08	0.00	0.08	--	0.00	0.005	0.01	0.002	0.008	0.025	0.03	0.05
Calcium	13.0	24.5	20	--	7	12.0	18	21	30	23.5	13.5	18
Magnes.	7.0	6.0	2.7	--	0.1	3.6	1.0	3.2	4.9	7.4	5.3	2.3
Sodium	11.5	11.0	8.5	--	6.0	3.5	7.0	5.8	7.7	13.2	13.5	8.5
Potass.	1.4	1.7	1.8	--	0.8	1.2	2.0	4.3	1.7	2.1	4.7	2.8
Mangan.	--	--	0.000	--	0.000	--	--	--	0.000	--	--	0.0
Silver	--	--	0.00	--	0.00	--	--	--	0.00	--	--	0.0
Tot.Sol.	114	127	118	180	166	116	100	135	120	150	115	132
Conduct.	214	234	192	130	129	130	135	167	182	228	240	226

% D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. monthly at McNary Dam



COLUMBIA RIVER AT McNARY DAM

Average Monthly Water Quality

1954 - 1957

FIG. 7

COLUMBIA RIVER AT McNARY DAM

Average Monthly Water Quality

1954-1957

FIG. 8

Table 7.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

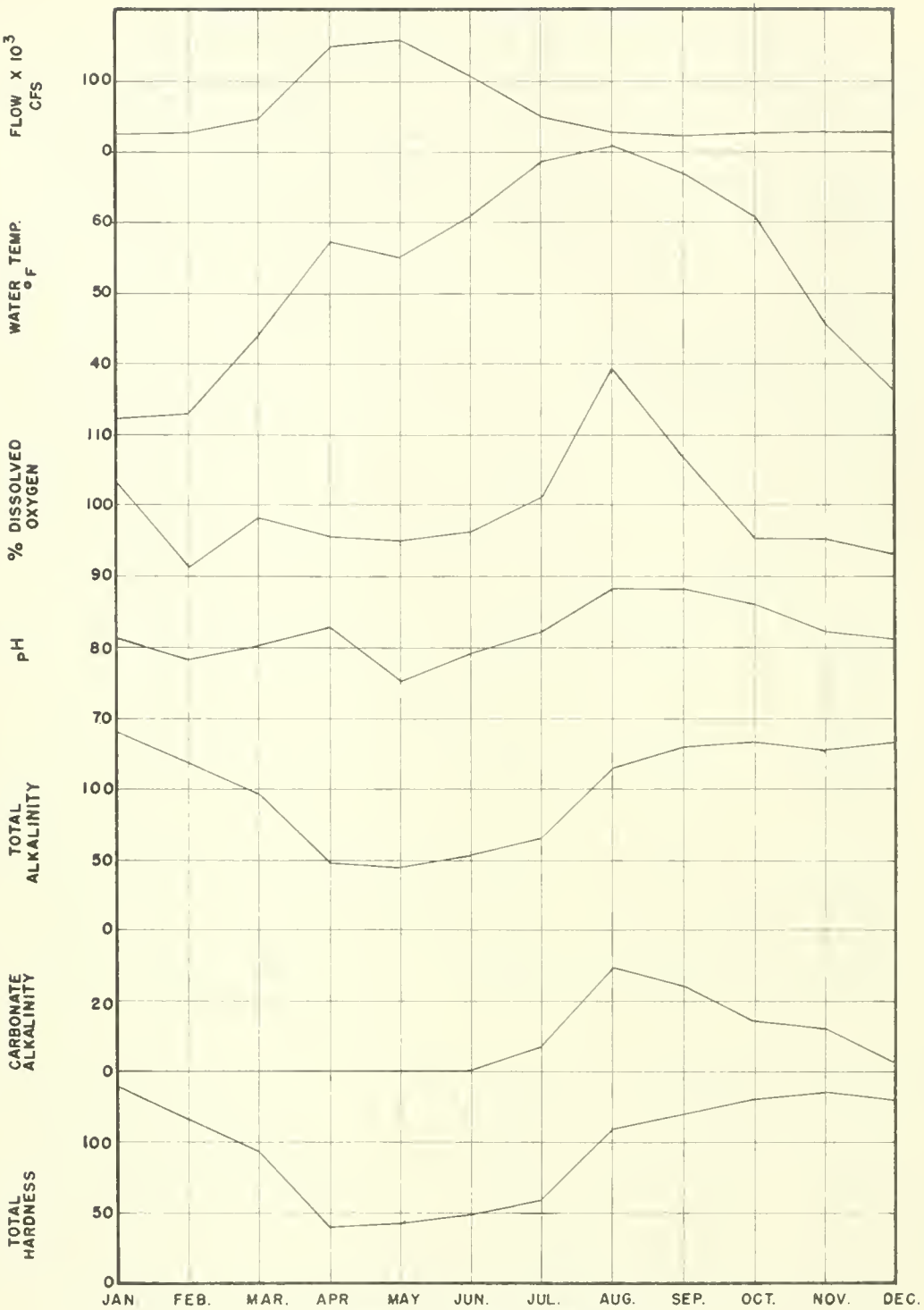
Sta: Snake R. at Mouth Sta. No.: 14 Designation: GS-326.2

Summary Period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	2,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	1	2	2	9	10	8	2	2	2
CFS 10^3	21	26	44	147	155	105	49	24	22	26	26	26
Water °F	32.0	32.7	43.4	51.1	55.0	60.6	68.4	70.6	66.8	60.8	45	35.5
Air °F[5]	20.3	37.3	43.8	56.1	61.1	68.1	72.9	71.8	63.2	51.9	42.2	36.9
Dis. Oxy.	15.0	13.1	12.1	10.7	10.1	9.6	9.28	10.7	9.9	9.8	11.4	13.0
% Satur.	103	91	98	95.5	94.9	96	101.0	119	106	95	95	93
Car. Di.	0.3	2.5	1.5	1.5	1.5	0.5	0.8	0	0	0	0	0.5
ph	8.1	7.8	8.0	8.25	7.5	7.9	8.2	8.8	8.8	8.6	8.2	8.1
Ammonia	T	T	0.05	0.24	0.09	0.55	0.25	T	0.10	T	T	T
Total Alk.	139	116	95	47	44	51	64	114	128	131	127	132
HCO_3^-	139	116	95	47	44	51	57	85	104	117	115	130
$CO_3^=$	0	0	0	0	0	0	7	29	24	14	12	2
Tot. Hard.	138	115	93	40	43	48	59	108	120	130	135	130
Car Hard.	138	115	93	40	43	48	59	108	120	130	127	130
N. C. H.	0	0	0	0	0	0	0	0	0	0	8	0
Sulfates	43	34	28	12	11.5	9.4	24	33	43	121	53	59
Color	18	50+	45	38	28	20	16	18	19	20	10	21
Turbid.	9	547*	104*	30	43	28	20	18	25	28	15	25
Iron	0.06	--	0.24	--	0.25	0.13	--	0.16	0.01	0.035	0.01	0.08
Copper	0.000	--	0.100	--	0.000	0.08	--	0.000	0.001	0.000	0.01	0.000
Zinc	--	--	0.0	--	0.0	--	--	0.0	0.0	--	0.0	0.0
Lead	--	--	0.0	--	0.0	--	--	0.0	0.0	--	0.0	0.0
Aluminum	0.04	--	0.03	--	0.00	0.02	--	0.11	0.03	0.01	0.00	0.06
Calcium	22.0	--	23.6	--	17	13.3	--	27.1	37.5	38.6	30	20
Magnes.	8.0	--	2.5	--	0.4	2.10	--	4.0	4.9	5.8	0.8	3.0
Sodium	34.0	--	20	--	5.0	9.80	--	28.0	29.4	37.0	38	20
Potass.	4.0	--	3.0	--	0.8	1.40	--	4.18	3.0	3.7	3.9	3.7
Mangan.	--	--	0.000	--	0.000	--	--	0.00	0.00	--	0.00	0.00
Silver	--	--	0.00	--	0.00	--	--	0.00	0.00	--	0.00	0.00
Tot.Sol.	279	675*	250*	240	162	133	149	221	273	289	201	259
Conduct.	435	369	162	125	102	123	173	332	354	433	405	414

& D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
* - High Silt load
5 - Avg. for month at Kennewick

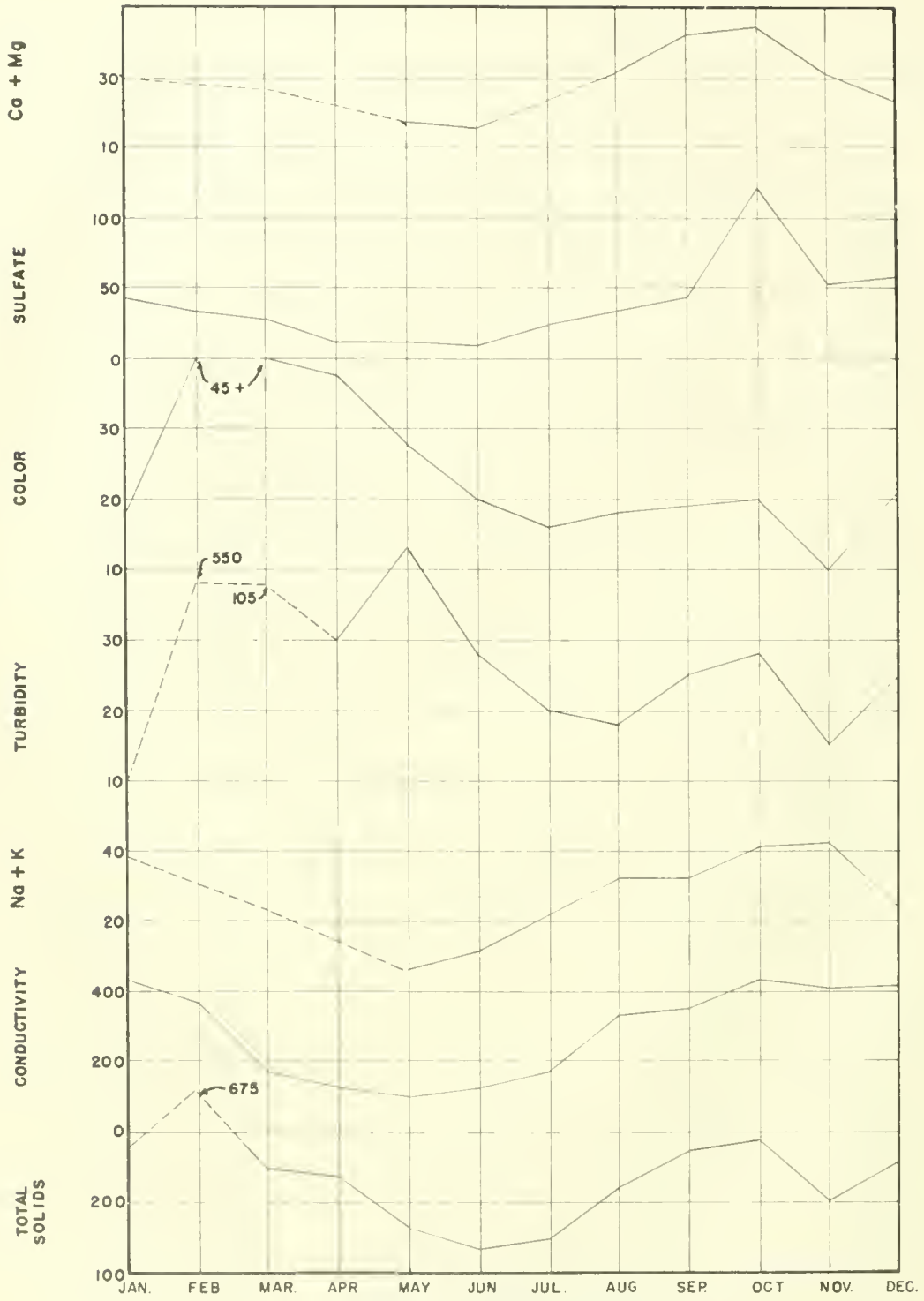


SNAKE RIVER AT MOUTH

Average Monthly Water Quality

1954 - 1957

FIG. 9



SNAKE RIVER AT MOUTH
Average Monthly Water Quality
1954 - 1957

FIG. 10

Table 8.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

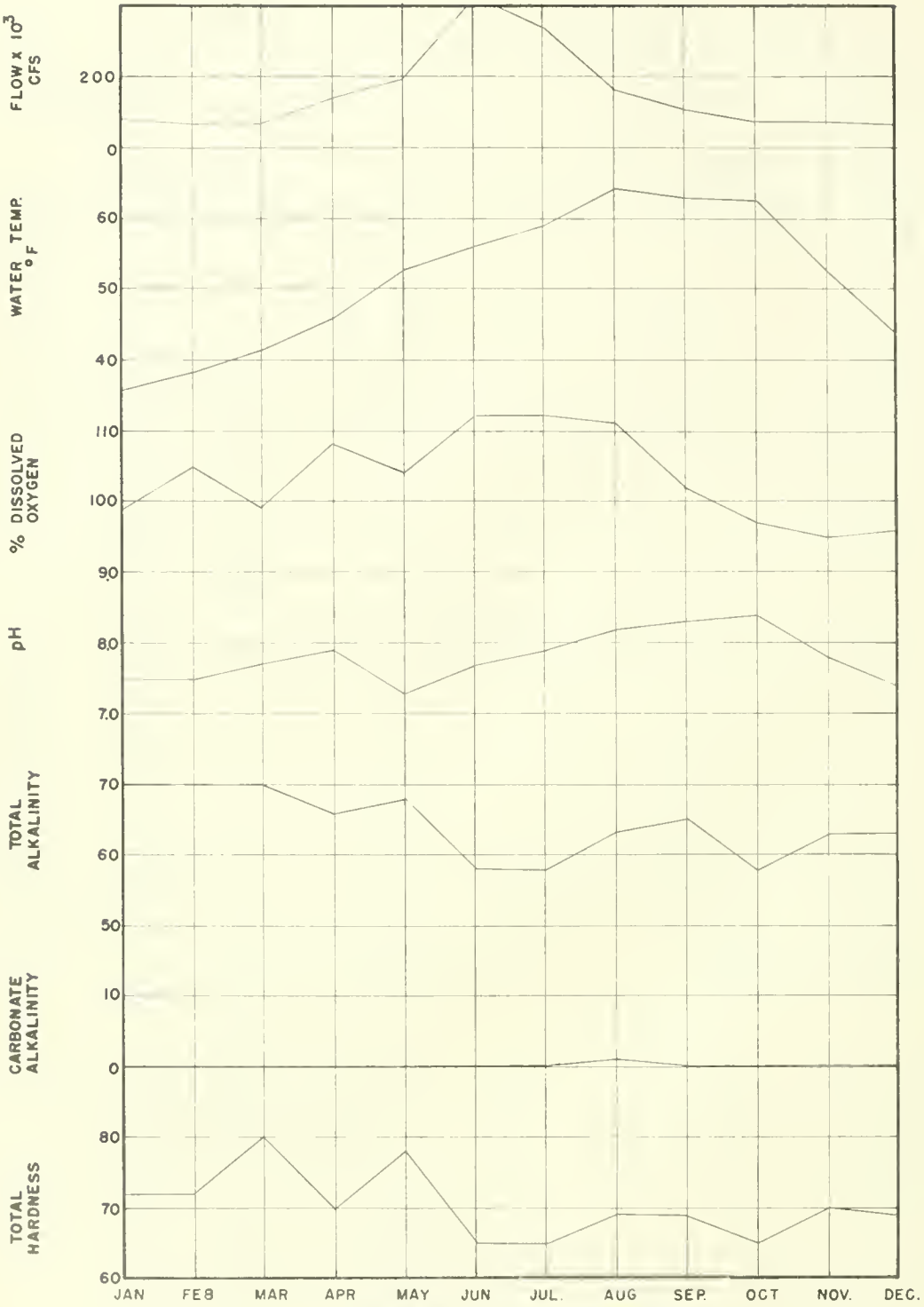
Sta: Columbia R. - Pasco Sta. No.: 16 Designation: C-328.5

Summary period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	1,2,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	1	2	3	8	10	8	2	2	2
CrS 10^3	87	70	74	115	197	425	340	162	107	73	70	66
Water °F	35.8	38.3	41.3	46.0	52.8	56.0	59	64.2	63.0	62.8	52.6	43.5
Air °F[5]	20.3	37.3	43.8	56.1	61.1	67.3	72.9	71.8	63.2	51.9	42.2	36.9
Dis. Oxy.	13.5	14.0	12.8	12.9	11.9	11.8	11.4	10.6	11.3	9.7	10.5	11.9
% Satur.	99	105	99	108	104	112	112	111	102	97	95	96
Var. Di.	1.0	2.3	2	1.5	T	0.9	0.9	0.4	0.7	1.3	1.0	1.2
pH	7.5	7.5	7.7	7.9	7.3	7.7	7.9	8.2	8.3	8.4	7.8	7.4
Ammonia	T	T	0.05	0.12	T	T	T	T	0.01	T	T	T
Total Alk	70	70	70	66	68	58	58	63	65	58	63	63
HCO_3^-	70	70	70	66	68	58	58	62	65	58	63	63
$CO_3^=$	0	0	0	0	0	0	0	1	T	0	0	0
Tot. Hard	72	72	80	70	78	65	65	69	69	65	70	69
Car Hard.	70	70	70	66	68	58	58	63	65	58	63	63
N. C. H.	2	2	10	4	10	7	7	6	4	7	7	6
Sulfates	9	14	16	16	15	8	8	10	16	12	8	11
Color	13	5	9	20	14	11	11	6	5	10	4	4
Turbid.	--	5	11	19	19	14	7	8	6	13	6	11
Iron	0.00	0.44	0.00	--	--	0.02	0.30	0.04	0.60	0.02	0.05	0.01
Copper	0.000	0.000	0.000	--	--	0.010	0.004	0.000	0.000	0.000	T	0.000
Zinc	--	--	--	--	--	--	0.0	0.0	0.0	--	0	--
Lead	--	--	--	--	--	--	0.0	0.0	0.0	--	0	--
Aluminum	0.02	0.02	0.03	--	--	0.00	0.00	0.08	0.01	0.04	0.06	0.00
Calcium	13.0	22.0	21.3	--	--	13.0	19	18.8	24	17.9	21	12.0
Magnes.	3.0	6.0	6.0	--	--	4.4	6	3.0	0.1	4.8	0.6	2.0
Sodium	5.0	5.5	3.0	--	--	2.0	1.0	1.5	1.0	3.5	2.0	0.5
Potass.	1.4	1.0	1.5	--	--	0.8	1.0	1.65	1.2	0.7	1.3	1.4
Mangan.	--	--	--	--	--	--	0.00	0.00	0.00	--	0	--
Silver	--	--	--	--	--	--	0.00	0.00	0.00	--	0	--
Tot.Sol.	--	88	110	160	124	115	95	118	92	90	77	89
Conduct.	167	181	182	155	145	119	128	146	140	149	158	169

* D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. monthly at Kennewick

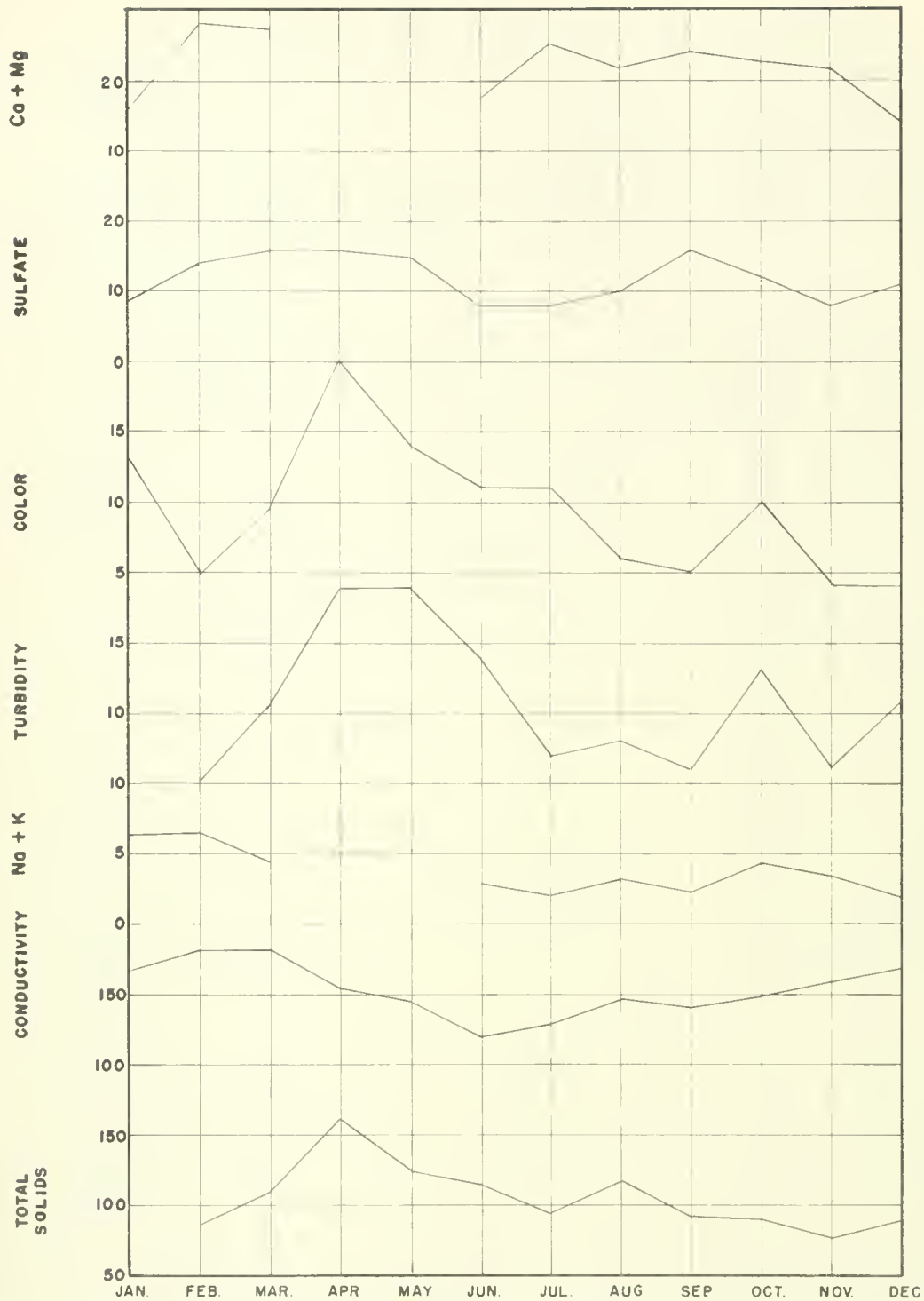


COLUMBIA RIVER AT PASCO

Average Monthly Water Quality

1954 - 1957

FIG. 11



COLUMBIA RIVER AT PASCO
Average Monthly Water Quality
1954 - 1957

FIG. 12

Table 9.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

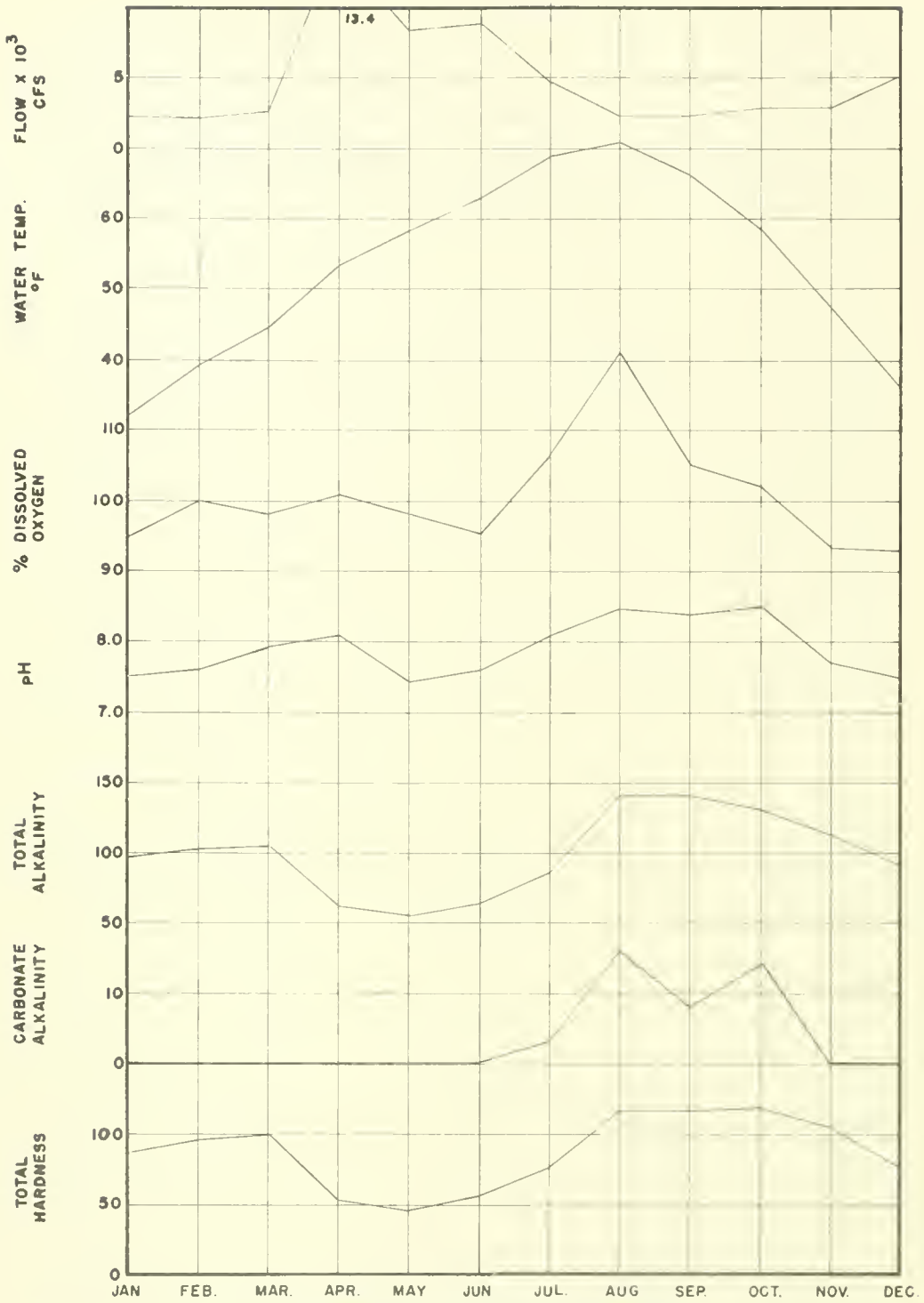
Sta: Yakima R. Enterprise Sta. No.: 17 Designation: CY-340

Summary period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	1,2,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	1	2	3	7	11	9	2	2	2
CrS 10^3	2.3	2.2	2.7	13.4	3.3	8.7	4.7	2.1	2.2	2.9	2.9	5.2
Water °F	32.0	39.0	44.4	53.7	58.5	63.1	69.1	71.1	66.3	58.6	47.5	36
Air °F[5]	20.8	38.0	44.5	57.5	62.6	68.6	75.7	74.2	66.8	54.3	44.0	37.8
Dis. Oxy.	13.9	13.1	12.0	10.3	10.0	9.3	9.7	10.8	10.2	10.5	11.0	12.7
% Satur.	95	100	98	101	98	95.5	107	121	106	102	93.5	93
Car. Di.	3.0	4.0	2	3.0	2.8	1.3	0.5	0	0.1	0	0.62	1.75
pH	7.5	7.6	7.9	8.1	7.4	7.6	8.1	8.5	8.4	8.5	7.7	7.5
Ammonia	T	T	0.05	0.13	0.10	0.28	0.12	0.07	0.06	T	T	T
Total Alk	97	102	105	62	55	65	87	141	141	131	112	90
HCO_3^-	97	102	105	62	55	65	84	125	133	117	112	90
$CO_3^=$	0	0	0	0	0	0	3	16	8	14	0	0
Tot. Hard	87	95	100	53	46	56	76	116	116	118	104	75
Car Hard.	87	95	100	53	46	56	76	116	116	118	104	75
N. C. H.	0	0	0	0	0	0	0	0	0	0	0	0
Sulfates	9	14	16	7	14	10	11	22	17	21	14	11
Color	10	5	18	40	26	18	18	12	10	18	7	10
Turbid.	18	27	25	34	66	32	28	16	15	20	18	24
Iron	0.04	0.03	0.15	--	0.01	0.13	--	0.06	0.15	0.03	0.05	0.05
Copper	0.000	0.040	0.0	--	0.0	0.05	--	0.0	0.20	0.0	0.012	0.000
Zinc	--	--	--	--	--	--	--	0.0	0.0	--	--	--
Lead	--	--	--	--	--	--	--	0.0	0.0	--	--	0.2
Aluminum	0.03	0.03	0.05	--	0.0	0.03	--	0.21	0.03	0.02	0.01	0.025
Calcium	11.0	27.0	12	--	1.0	13.5	--	28	33	38	20	13
Magnes.	4.4	5.5	4.5	--	0.5	2.1	--	3.4	4.3	8.2	2.2	1.1
Sodium	4.5	17.0	14	--	3.0	15.5	--	22.7	15.5	21	20	9
Potass.	1.6	2.4	2.5	--	0.2	1.8	--	5.1	3.0	3.3	3.0	2.9
Mangan.	--	--	--	--	--	--	--	0.0	0.0	--	--	0.0
Silver	--	--	--	--	--	--	--	0.0	0.0	--	--	0.0
Tot.Sol.	186	164	178	310	226	190	182	208	228	228	194	149
Conduct.	230	274	256	134	156	135	185	311	308	324	280	222

% D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. monthly at Richland



YAKIMA RIVER AT ENTERPRISE

Average Monthly Water Quality

1954-1957

FIG. 13

YAKIMA RIVER AT ENTERPRISE

Average Monthly Water Quality

1954 - 1957

FIG. 14

Table 10.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

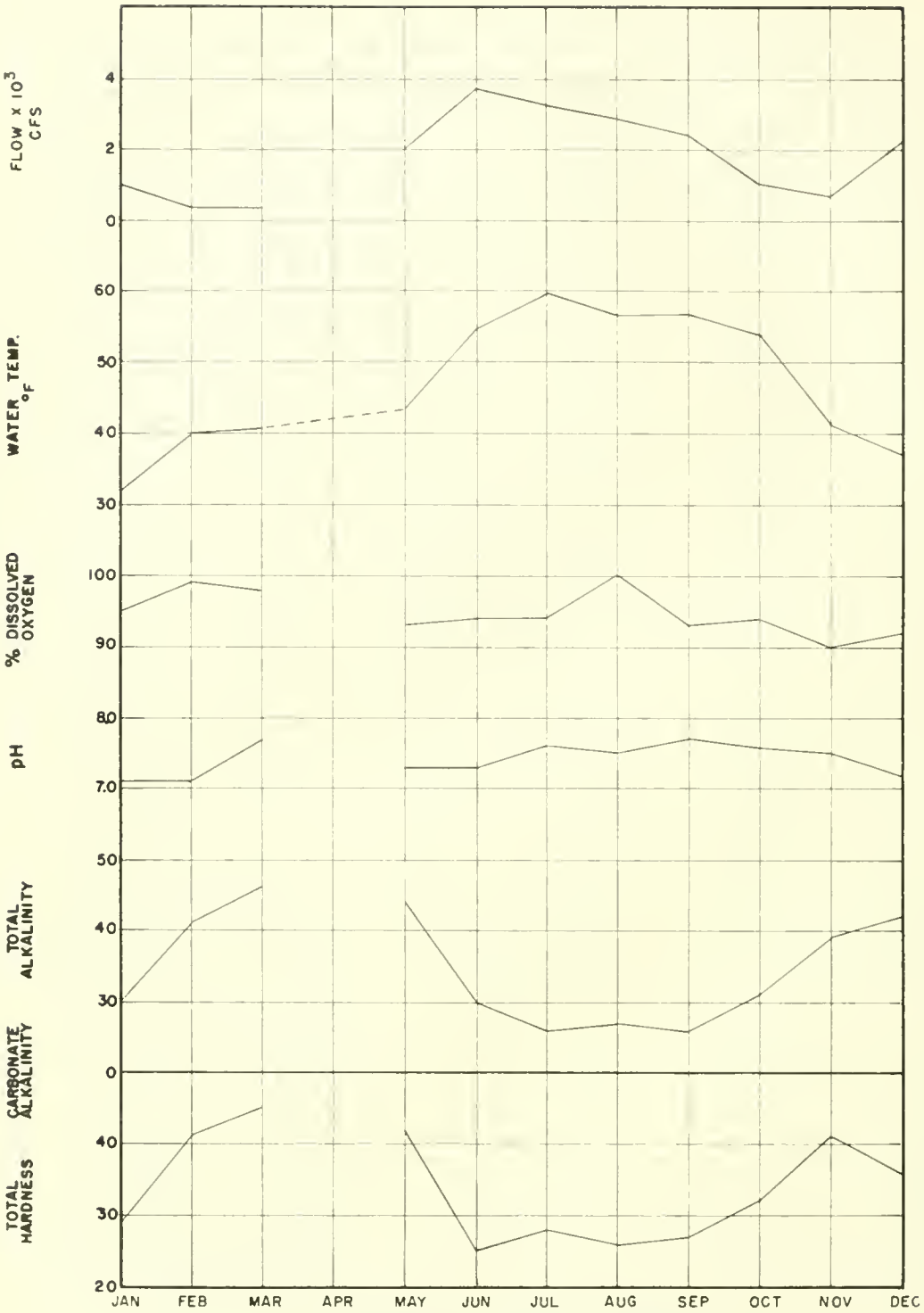
Sta: Yakima River above Thorp Sta. No.: 22 Designation: CY 493

Summary period. 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4		2	1,2,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	0	1	3	7	9	7	2	2	2
Cfs 10^3	1.0	0.4	0.4		2.0	3.7	3.2	2.9	2.4	1.0	0.7	2.2
Water °F	32	39.8	40.4		43.2	54.7	59.7	56.4	56.6	53.9	41.0	37.0
Air °F 5	15.4	31.0	36.7		51.3	59.7	62.9	65.9	58.6	46.9	38.4	30.4
Dis. Oxy.	13.9	12.8	12.6		11.6	10.0	9.5	10.4	9.7	10.0	11.4	12.5
% Satur.	95	99	98		93	94	94	100	93	94	90	92
Car. Di.	2.0	5.0	2		1.5	1.1	0.9	0.9	1.2	3.0	1.5	1.25
pH	7.1	7.1	7.7		7.3	7.3	7.6	7.5	7.7	7.6	7.5	7.2
Ammonia	T	T	0.04		0.04	0.19	T	0.05	0.05	T	T	T
Total Alk	30	41	46		44	30	26	27	26	31	39	42
HCO_3^-	30	41	46		44	30	26	27	26	31	39	42
$CO_3^=$	0	0	0		0	0	0	0	0	0	0	0
Tot. Hard	29	41	45		42	25	28	26	27	32	41	36
Car Hard.	29	41	45		42	25	26	26	26	31	39	36
N. C. H.	0	0	0		0	0	2	0	1	1	2	0
Sulfates	3	3	6		6	1	1	1	2	5.0	3	3
Color	8	20	25		20	12	8	8	7	11	12	6
Turbid.	12	43	43		54	33	4	7	6	22	40	19
Iron	0.01	0.02	0.25		0.20	0.15	--	0.12	0.10	0.04	0.03	0.03
Copper	0.026	0.030	0.000		0.000	0.008	--	0.000	0.00	0.001	0.000 (3)	0.03
Zinc	--	--	--		--	--	--	0.00	0.00	--	--	--
Lead	--	--	--		--	--	--	0.000	0.00	--	--	--
Aluminum	0.04	0.00	0.06		0.000	0.05	--	0.33	0.02	0.02	0.000	0.80
Calcium	2.0	12.0	8.7		9	13.0	--	7.4	22.7	9.4	9.6	60
Magnes.	3.0	2.2	1.6		0.10	0.10	--	1.15	1.4	1.7	1.0	3.0
Sodium	4.5	5.0	4.0		3.0	2.0	--	1.42	0.7	7.25	2.5	3.0
Potass.	1.8	4.8	0.8		0.4	0.4	--	2.25	0.8	1.35	2.4	3.8
Mangan.	--	--	--		--	--	--	0.00	0.00	--	--	--
Silver	--	--	--		--	--	--	0.00	0.00	--	--	--
Tot.Sol.	60	68	98		74	65	57	42	31	68	63	72
Conduct.	81	107	105		84	53	53	51	51	77	90	134

* D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. monthly at Ellensburg

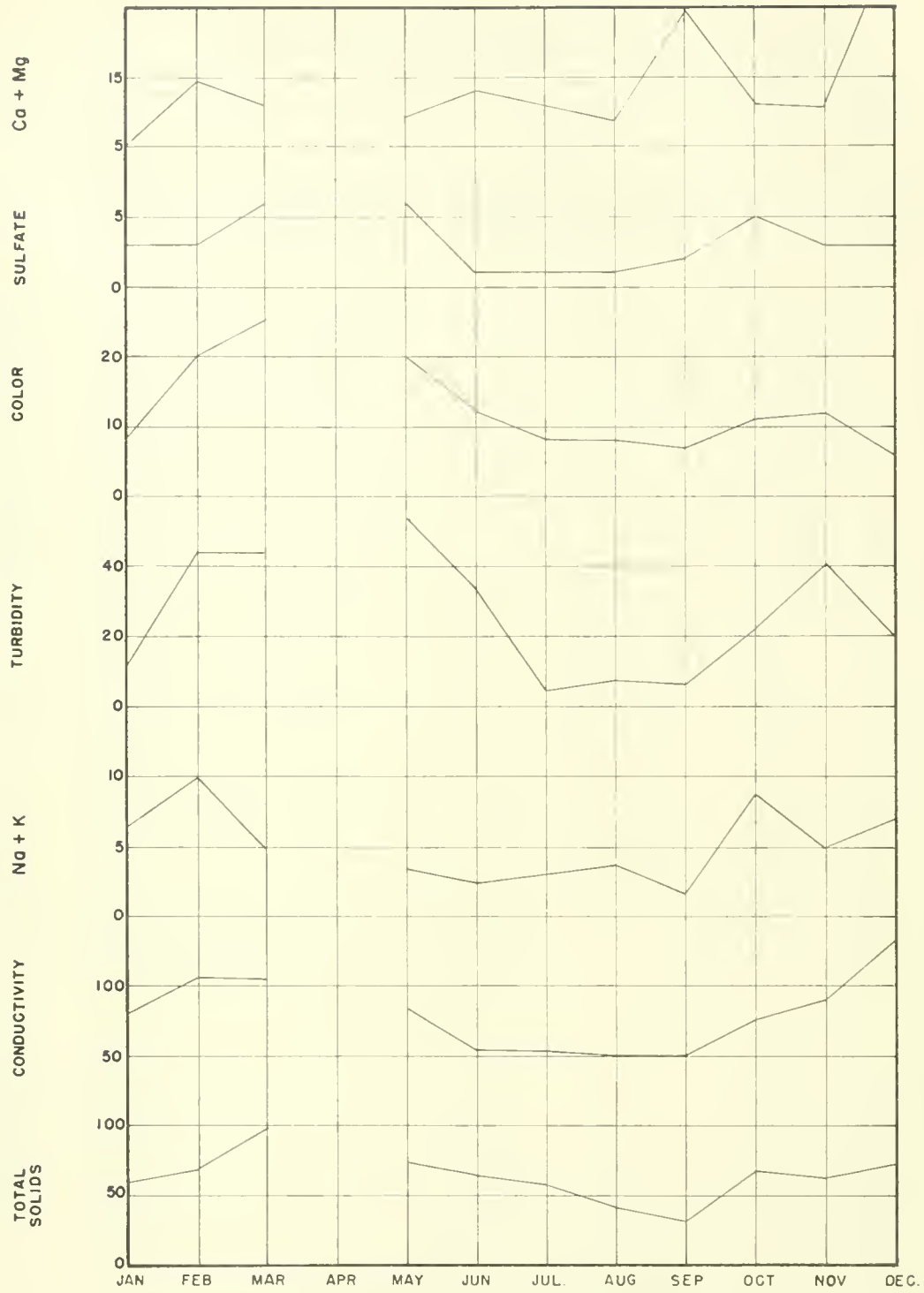


YAKIMA RIVER ABOVE THORPE

Average Monthly Water Quality

1954 - 1957

FIG. 15



YAKIMA RIVER ABOVE THORPE

Average Monthly Water Quality

1954 - 1957

FIG. 16

Table 11.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

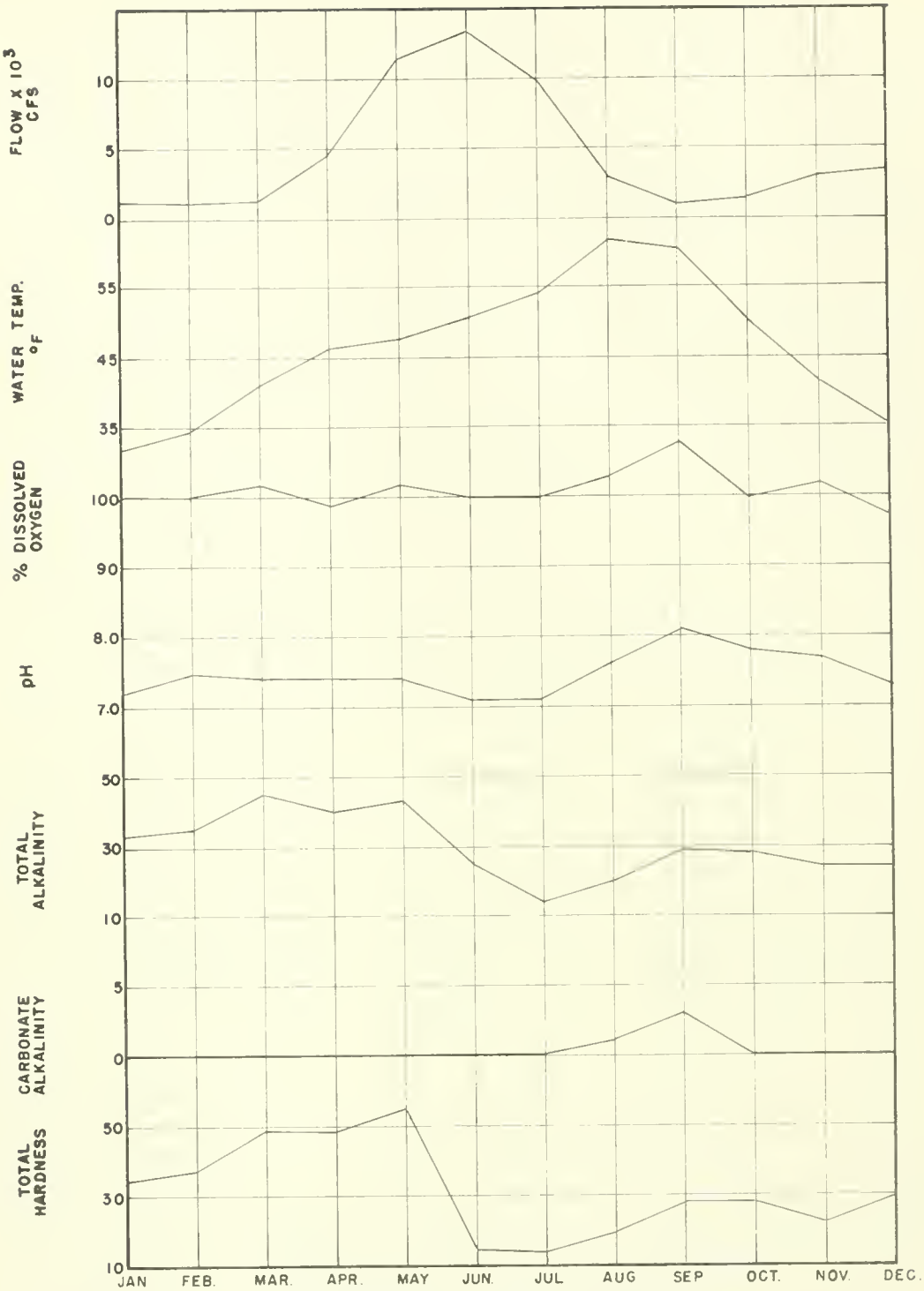
Sta: Wenatchee River near Mouth Sta. No.: 23 Designation: CW - 471

Summary Period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	3,4	3,4	2,3,4	3	2,3	1,2,3	1,2,3	1,2,3	1,2,3	2,3	1,2,3	1,2,3
Samples	2	2	3	1	2	3	8	8	6	4	4	3
CFS 10^3	1.1	1.0	1.1	4.6	11.3	13.3	9.8	2.9	1.0	1.5	2.8	3.3
Water °F	32.0	34.5	41.9	46.2	47.6	50.7	54.1	61.7	60.5	50.2	41.7	35.2
Air °F[5]	22.6	25.0	38.9	54.2	59.1	64.7	71.4	70.6	62.7	49.3	36.9	29.4
Dis. Oxy.	14.4	14.2	12.7	11.5	11.8	11.1	10.6	10.1	10.6	11.1	12.7	13.4
% Satur.	99	100	101	97	102	99	99	103	106	98	100	97
Car. Di.	1.5	4.25	1.7	2.5	1.75	1.33	1.3	1.2	0.4	1.4	1.4	1.5
ph	7.2	7.47	7.4	7.4	7.4	7.1	7.1	7.6	8.1	7.8	7.7	7.3
Ammonia	0.14	0.08	0.08	0.25	0.04	0.08	0.17	0.08	0.07	0.11	0.10	0.13
Total Alk	33	35	45	40	43	25	14	20	29	28	24	24
HCO_3^-	33	35	45	40	43	25	14	19	26	28	24	24
$CO_3^=$	0		0	0	0	0	0	1	3	0	0	0
Tot. Hard	34	37	48	48	55	14	14	19	28	28	22	29
Car Hard.	33	35	45	40	43	14	14	19	28	28	22	24
N. C. H.	1	2	3	8	12	0	0	0	0	0	0	5
Sulfates	3.6	3.9	3.1	4.6	3.1	1.0	1.4	1.7	2.1	3.6	1.2	2.5
Color	10	8	20	48	17	8	9	6	5	7	7	7
Turbid.	9	5	40	80	18	11	5	8	13	10	4	11
Iron	0.02	--	0.01	--	--	0.02	0.01	0.02	0.03	0.03	0.00	0.00
Copper	0.000	--	0.000	--	--	0.000	0.000	0.00	0.00	0.00	0.000	0.010
Zinc	--	--	--	--	--	--	0.00	--	--	--	--	--
Lead	--	--	--	--	--	--	0.00	--	--	--	--	--
Aluminum	0.02	--	0.06	--	--	0.005	0.00	0.00	0.01	0.03	0.09	0.03
Calcium	2.2	--	10.9	--	--	5.0	8.5	23.2	9.9	10.4	0.5?	2.0
Magnes.	3.2	--	3.6	--	--	0.8	0.3	1.8	3.8	1.2	2.4	1.0
Sodium	2.0	--	2.5	--	--	1.8	2.5	1.5	2.0	2.0	1.0	3.0
Potass.	1.3	--	1.6	--	--	1.2	2.5	1.4	1.6	0.4	2.6	0.8
Mangan.	--	--	--	--	--	--	0.0	--	--	--	--	--
Silver	--	--	--	--	--	--	0.0	--	--	--	--	--
Tot.Sol.	58	76	77	270	115	53	39	49	46	45	45	41
Conduct.	68	78	94	94	54	37	32	46	60	63	50	58

% D. O. satur. is at sea level; alk. hardness and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. Monthly at Wenatchee

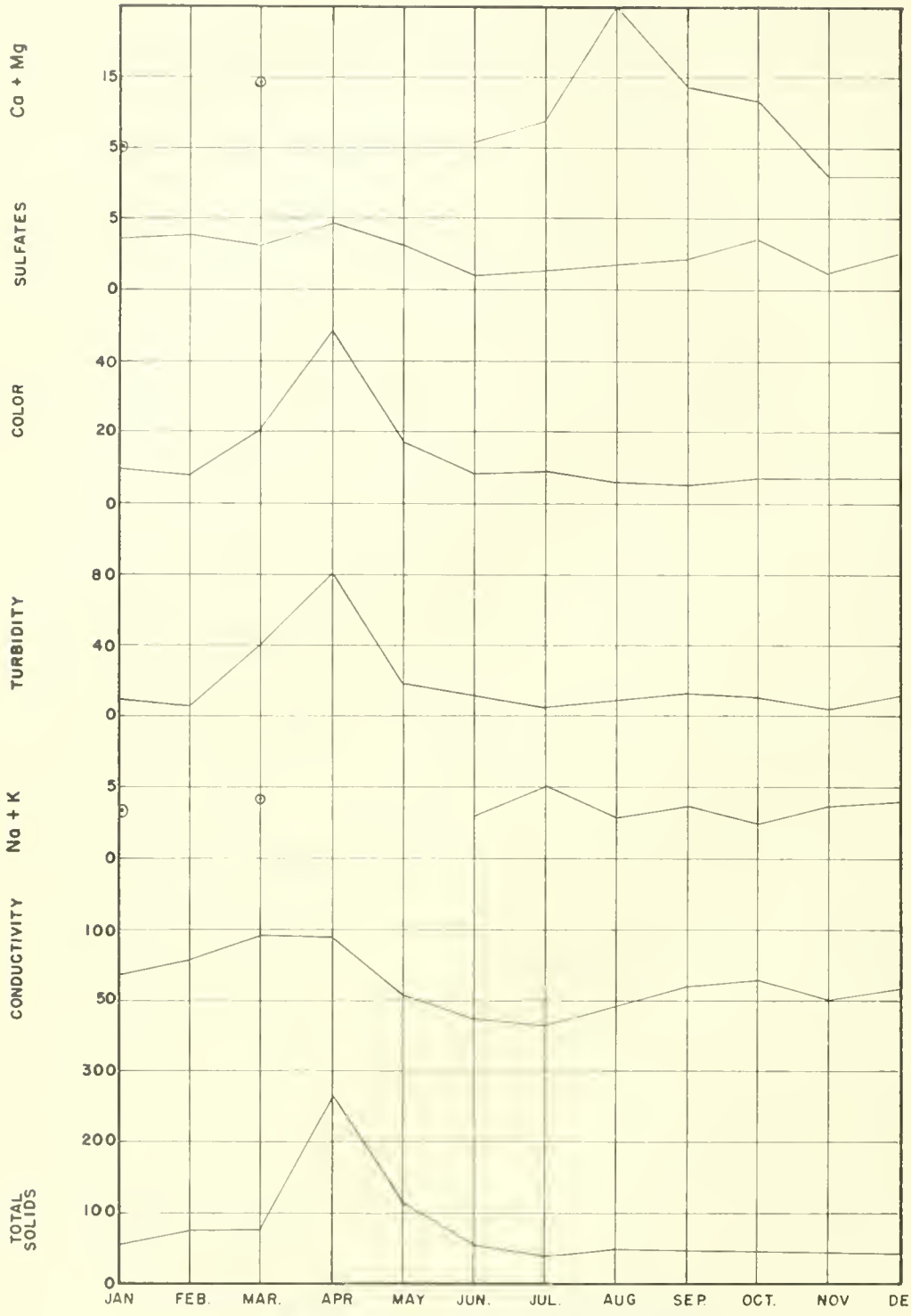


WENATCHEE RIVER NEAR MOUTH

Average Monthly Water Quality

1954 - 1957

FIG. 17



WENATCHEE RIVER NEAR MOUTH

Average Monthly Water Quality

1954-1957

FIG. 18

Table 12.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

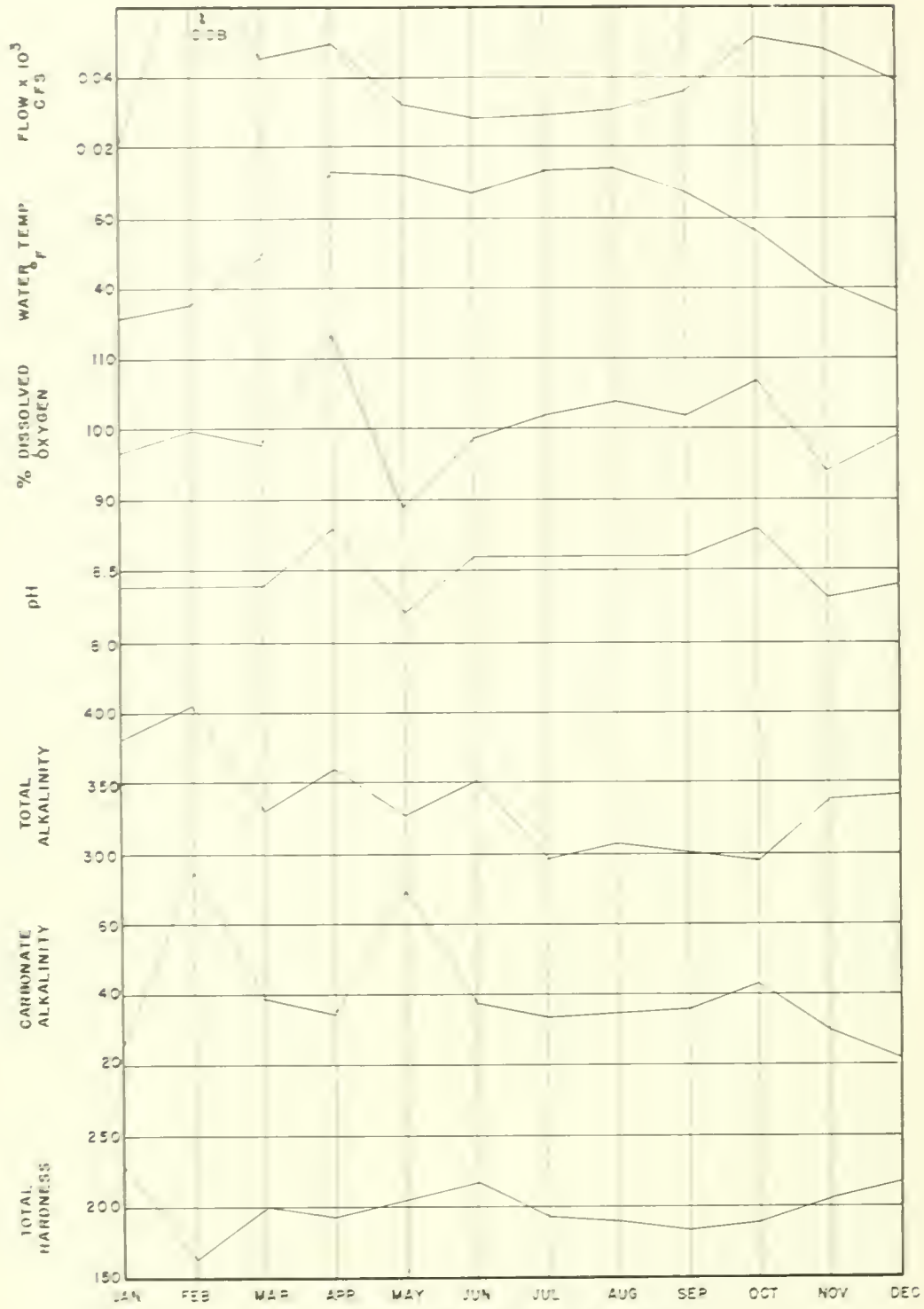
Sta: Crab Creek at Beverly Sta. No.: 37 Designation: CCb - 411

Summary Period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	1,2,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	1	2	3	7	7	8	2	2	2
CFS 10^3	0.021	0.081	0.045	0.050	0.032	0.028	0.029	0.031	0.036	0.051	0.048	0.039
Water °F	32.0	36.3	49.0	73.0	72.2	67.7	73.1	73.9	67.7	57.3	42.0	33.2
Air °F[5]	17.0	33.0	41.3	54.8	56.2	65.9	74.9	73.0	64.4	51.8	40.7	33.3
Dis. Oxy.	14.2	13.7	11.2	10.1	7.8	9.1	8.9	8.9	9.4	11.1	11.8	14.3
% Satur.	97	100	98	114	89	99	102	104	102	107	94	99
Par. Di.	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pH	8.4	8.4	8.4	8.8	8.2	8.6	8.6	8.6	8.6	8.8	8.3	8.4
Ammonia	T	T	0.02	0.15	0.13	0.22	0.09	0.07	0.10	T	T	T
Total Alk	381	404	330	360	327	352	297	306	300	294	337	341
HCO_3^-	355	329	301	325	258	314	263	271	264	251	307	319
$CO_3^=$	26	75	29	35	69	38	34	35	36	43	30	22
Tot. Hard	228	163	200	194	205	218	193	190	184	189	205	216
Car Hard	228	163	200	194	205	218	193	190	184	189	205	216
N. C. H.	0	0	0	0	0	0	0	0	0	0	0	0
Sulfates	174	77	85	144	91	148	114	126	100	172	87	125
Color	20	50	38	35	29	93	43	36	34	40	30	21
Turbid.	18	43	41	175	150	211	166	219	146	60	51	38
Iron	0.05	0.02	0.25	--	0.150	0.08	--	0.36	0.13	0.04	0.06	0.15
Copper	0.006	0.040	0.000	--	0.000	0.002	--	0.000	0.001	0.000	0.002	0.000
Zinc	--	--	0.000	--	0.000	--	--	0.000	0.000	--	0.000	--
Lead	--	--	0.000	--	0.000	--	--	0.000	0.000	--	0.000	--
Aluminum	0.06	0.01	0.100	--	0.010	0.025	--	0.140	0.002	0.002	0.000	0.04
Calcium	27.0	33.0	62	--	31	24	--	40	42	63	19	23
Magnes.	9.0	20.0	6.8	--	0.10	7.2	--	5.8	4.9	10.0	0.8	4.7
Sodium	123	19.0	117	--	120	68.5	--	105	102	126	102	135
Potass.	13.9	25.0	13.1	--	16.6	27.5	--	25.6	13.0	6.9	13.0	13
Manган.	--	--	0.000	--	0.000	--	--	0.000	0.000	--	0.000	--
Silver	--	--	0.000	--	0.000	--	--	0.000	0.000	--	0.000	--
Tot.Col.	705	691	650	904	749	769	675	831	640	636	631	618
Conduct.	1065	1135	900	1180	853	933	815	845	861	937	953	1000

Avg. G. water. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. Monthly at Smyrna

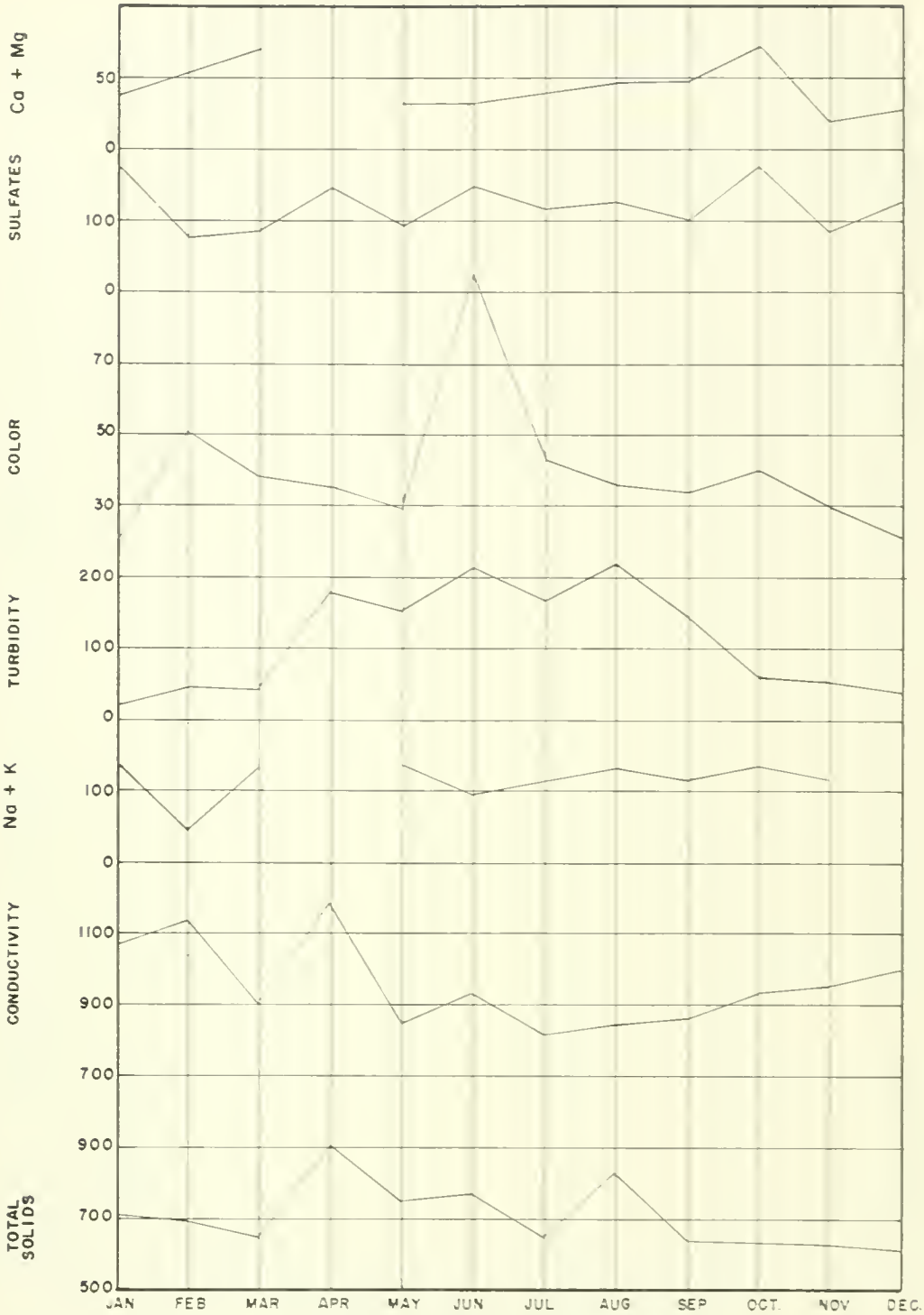


CRAB CREEK AT BEVERLY

Average Monthly Water Quality

1954-1957

FIG. 19



CRAB CREEK AT BEVERLY

Average Monthly Water Quality

1954 - 1957

FIG. 20

Table 13.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

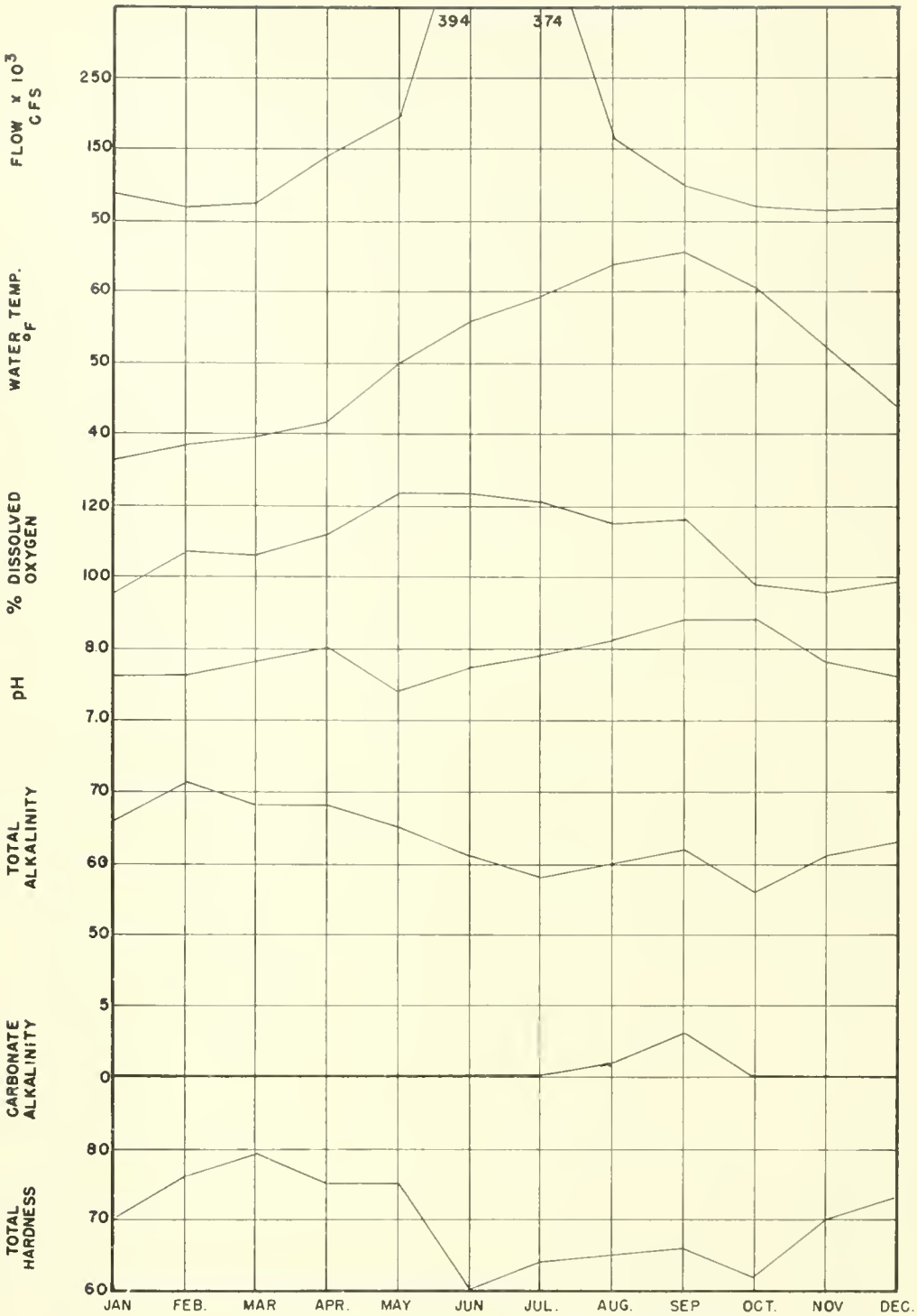
Sta: Columbia River below Vantage Sta. No.: 38 Designation: C 409

Summary Period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	1,2,3	1,2,3	1,2,3	1,2,3	3	1,3	1,3
Samples	1	1	2	1	2	3	8	7	8	2	2	2
CFS 10^3	85	68	71	141	193	394	374	163	99	71	64	67
Water °F	36.8	38.3	39.5	41.7	50.0	55.9	59.1	64.2	65.6	60.7	52.2	43.5
Air °F[5]	17.0	33.0	41.3	54.8	56.2	65.9	74.9	73.0	64.4	51.8	40.7	33.3
Dis. Oxy.	13.0	14.2	13.7	14.2	14.0	13.0	12.2	11.1	10.9	9.8	10.5	12.3
% Satur.	96	107	106	112	123	123	121	115	116	98	96	99
Car. Di.	2.0	4.0	2.0	1.5	1.0	0.8	1.6	0.3	0.12	2.5	1.75	1.2
pH	7.6	7.6	7.8	8.0	7.4	7.7	7.9	8.1	8.4	8.4	7.8	7.6
Ammonia	T	T	0.20	0.09	0.09	0.22	0.08	0.12	0.10	T	T	T
Total Alk	66	71	68	68	65	61	58	60	62	56	61	63
HCO_3^-	66	71	68	68	65	61	58	59	59	56	61	63
$CO_3^=$	0	0	0	0	0	0	0	1	3	0	0	0
Tot. Hard	70	76	79	75	75	60	64	65	66	62	70	73
Car Hard.	66	71	68	68	65	60	58	60	62	56	61	63
N. C. H.	4	5	11	7	10	0	6	5	4	6	9	10
Sulfates	8	9	20	16	12	7	9	8	9	13	11	13
Color	5	5	8	15	12	12	13	7	6	8	5	37
Turbid.	3	9	16	9	22	16	7	8	5	10	8	13
Iron	0.00	0.01	0.25	--	0.10	--	0.04	0.04	0.10	0.02	0.00	0.03
Copper	0.000	0.000	0.000	--	0.000	--	0.003	0.005	0.030	0.000	0.002	0.000
Zinc	--	--	0.000	--	0.000	--	0.000	0.000	0.000	--	0.000	0.000
Lead	--	--	0.000	--	0.000	--	0.000	0.000	0.000	--	0.000	0.000
Aluminum	0.01	0.01	0.12	--	0.000	--	0.010	0.010	0.010	0.000	0.000	0.05
Calcium	12.0	26.0	22.3	--	22	--	17	21.3	21	23.1	19	15
Magnes.	5.0	4.0	3.2	--	0.4	--	6.0	2.15	0.50	2.65	0.60	1.1
Sodium	4.5	6.0	4.3	--	4.0	--	1.0	3.75	2.0	3.25	15.0	11
Potass.	1.6	1.5	1.4	--	1.4	--	1.0	1.7	1.2	1.6	1.9	1.1
Mangan.	--	--	0.000	--	0.000	--	0.000	0.000	0.000	--	0.000	0.000
Silver	--	--	0.000	--	0.000	--	0.000	0.000	0.000	--	0.000	0.000
Tot. Sol.	93	95	152	182	132	98	95	94	86	84	93	83
Conduct.	157	196	181	190	146	123	134	138	143	142	183	186

D. O. satur. is at sea level; salinity and hardness as equivalent $CaCO_3$; conductivity in micromhos. c.c. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
4 - 1957
5 - Avg. Monthly at Smyrna

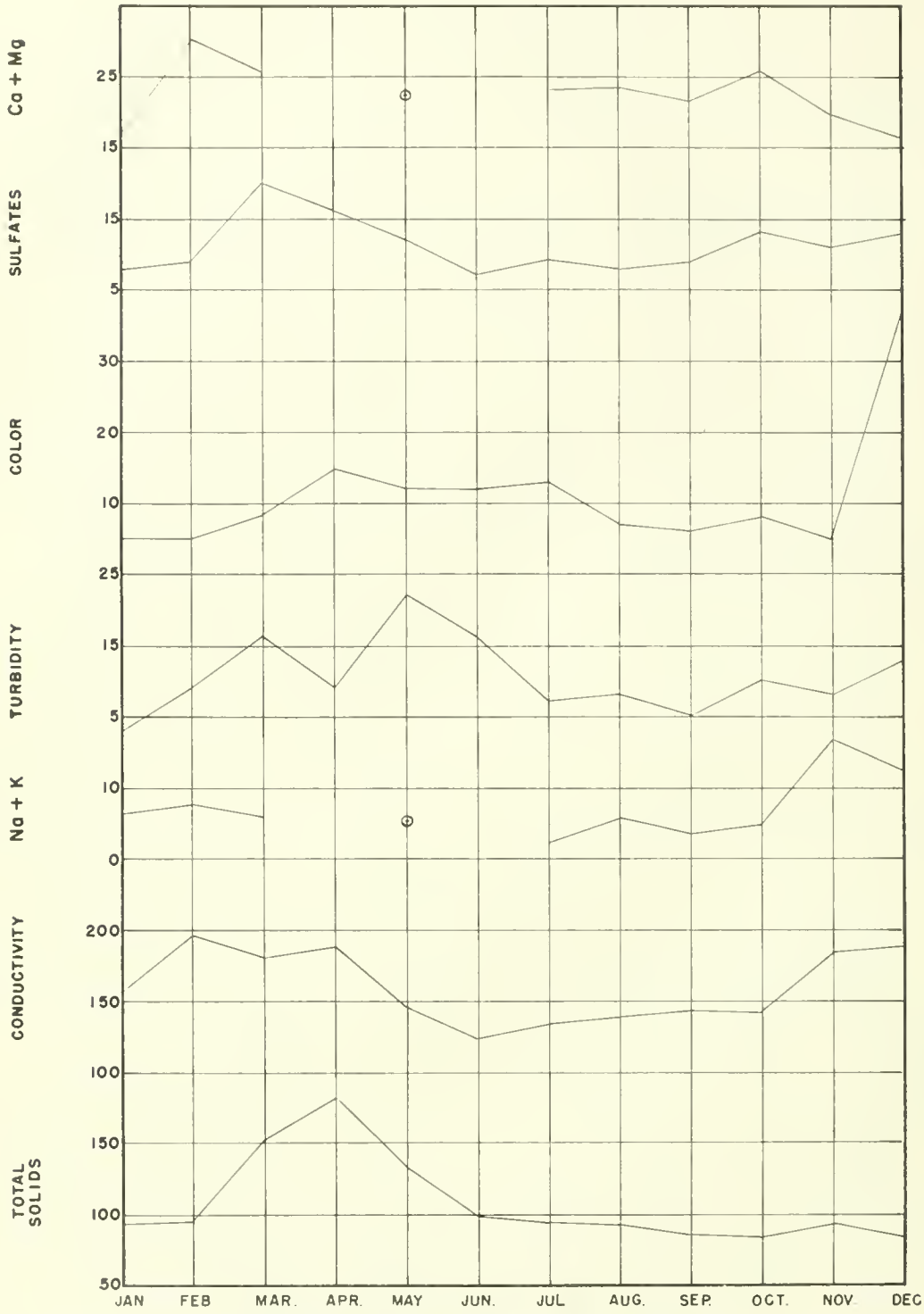


COLUMBIA RIVER BELOW VANTAGE

Average Monthly Water Quality

1954 - 1957

FIG. 21



COLUMBIA RIVER BELOW VANTAGE

Average Monthly Water Quality

1954 - 1957

FIG. 22

Table 14.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

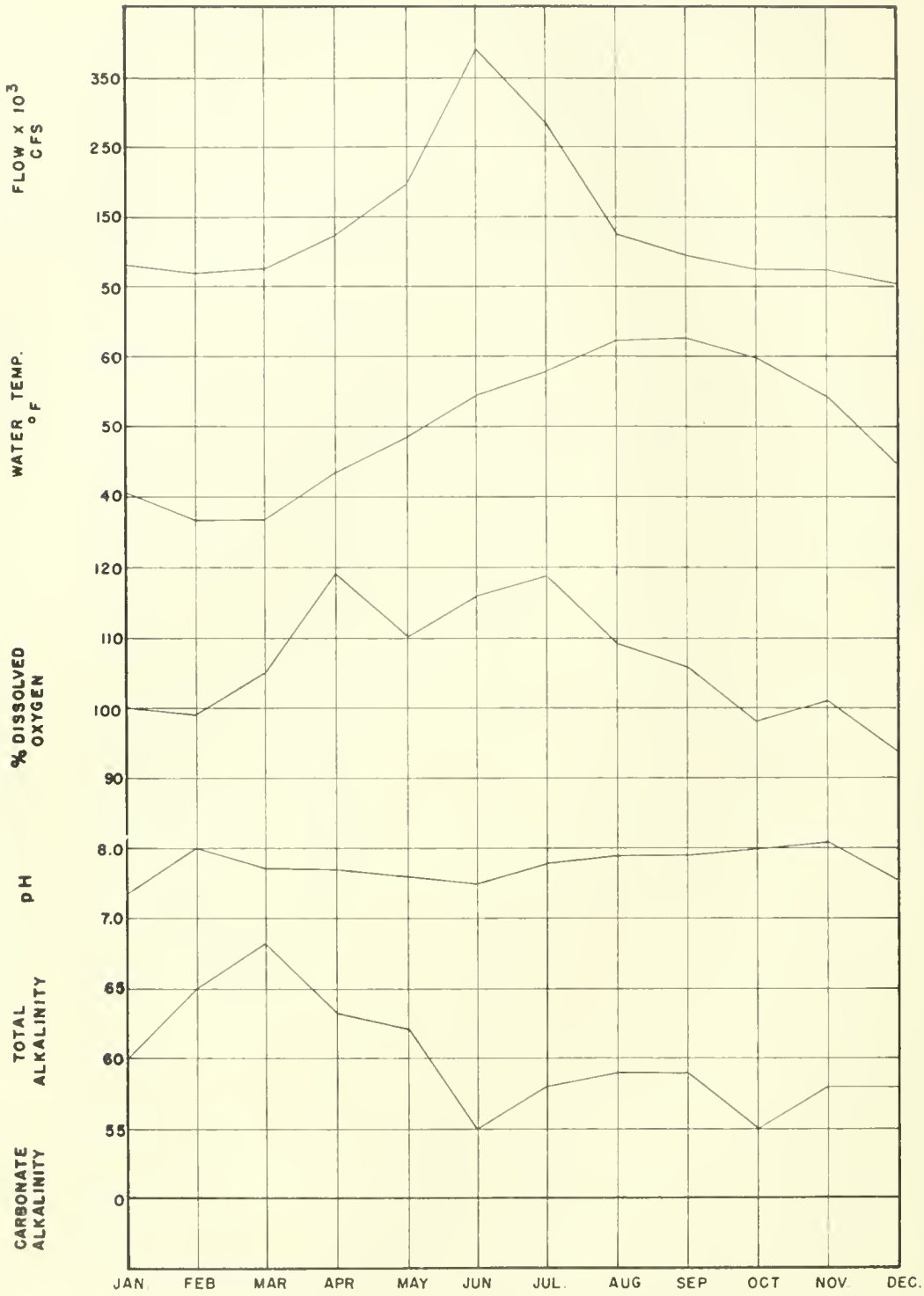
Sta: Columbia River at Rock Island Sta. No.: 40 Designation: C - 453.4

Summary period: 1954 - 55 - 56 - 57

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	4	4	2,4	3	2,3	1,2,3	1,2,3	1,2,3	1,2,3	3	3	3
Samples	1	1	2	1	2	3	8	8	7	2	2	1
CFS 10^3	80	70	73	126	197	390	287	126	95	74	73	53
Water °F	40.5	36.9	36.9	43.7	48.5	54.5	58.0	62.2	62.7	60.0	54.4	45.1
Air °F [5]	18.6	32.2	41.7	57.5	62.4	67.8	75.8	75.3	66.7	53.7	37.9	33.4
Dis. Oxy.	12.8	13.3	14.1	14.3	13.3	12.7	12.2	10.7	10.4	9.8	10.8	11.3
% Satur.	100	99	105	119	110	116	119	109	106	98	101	94
Car. Di.	2.5	7.0	2.0	2.0	1.7	1.6	1.4	1.2	0.9	2.0	1.2	2.0
ph	7.35	8.01	7.7	7.7	7.6	7.5	7.8	7.9	7.9	8.0	8.1	7.55
Ammonia	T	T	0.02	0.24	0.04	0.05	0.04	0.05	0.08	T	T	T
Total Alk	60	65	68	63	62	55	58	59	59	55	58	58
HCO_3^-	60	65	68	63	62	55	58	59	59	55	58	58
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot. Hard	71	73	78	72	74	61	62	64	65	64	64	65
Car Hard.	60	65	68	63	62	55	58	59	59	55	58	58
N. C. H.	11	8	10	9	12	6	4	5	6	9	6	7
Sulfates	15	12	12	16	17	8.0	7.8	7.5	8.3	8.2	10	15
Color	5	5	12	20	18	8	10	6	4	10	5	10
Turbid.	13	2	23	20	15	13	7	8	6	12	5	13
Iron	--	--	--	--	--	--	--	--	--	--	--	--
Copper	--	--	--	--	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--	--	--	--	--
Calcium	--	--	--	--	--	--	--	--	--	--	--	--
Magnes.	--	--	--	--	--	--	--	--	--	--	--	--
Sodium	--	--	--	--	--	--	--	--	--	--	--	--
Potass.	--	--	--	--	--	--	--	--	--	--	--	--
Mangan.	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	69	108	121	113	141	83	81	84	83	55	123	76
Conduct.	137	147	157	154	140	115	126	129	135	125	128	130

% D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

1 - 1954
2 - 1955
3 - 1956
T - Trace
(4) 1957
5 - Avg. Monthly at Trinidad

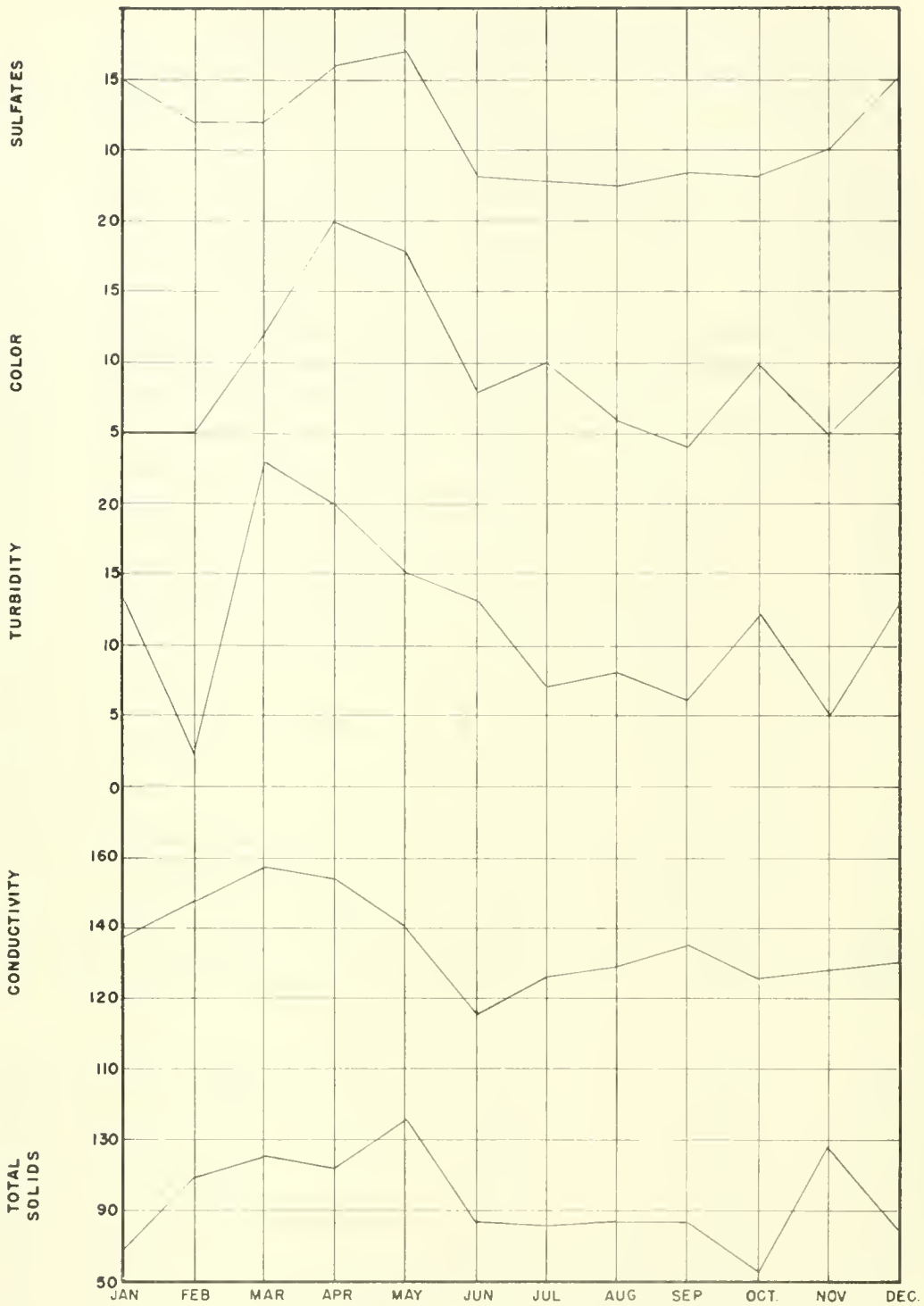


COLUMBIA RIVER AT ROCK ISLAND

Average Monthly Water Quality

1954 - 1957

FIG. 23



COLUMBIA RIVER AT ROCK ISLAND

Average Monthly Water Quality

1954 - 1957

FIG. 24

Table 15.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

Sta: Nason Creek (Near Mouth) Sta. No.: 43 Designation: CWNa 523

Summary period: June 1955 - March 1957

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	2,3		2,3	2	2	1,2	1,2	1,2	1,2	1,2	2	1,2
Samples	2	Stream Frozen	2	1	1	2	5	4	4	4	2	2
CFS 10^3	0.222	0.207	0.207	0.078	1.470	1.690	1.000	0.280	0.110	0.300	0.530	0.560
Water °F	32.0		37.6	38.5	41	44.9	53.2	59.4	55.6	43.2	37.0	35.0
Air °F [4]	18.2		36.2*	47.2	58.1	56.8	64.8	64.2	56.4	44.0	31.5	25.1
Dis. Oxy.	13.1		12.3	12.1	11.8	10.8	10.1	9.5	10.8	10.9	12.7	12.3
% Satur.	90		92	92	92	90	93	94	102	89	94	88
Car. Di.	1.5		2	2.0	2.0	1.6	1.8	2	1.2	1.8	1.7	1.2
pH	6.9		7.0	6.9	7.7	6.68	6.84	7.3	7.3	7.0	6.7	6.8
Ammonia	0.13		0.1	0.23	0.18	0.17	0.14	0.20	0.10	0.16	0.0	0.3
Total Alk	15		17	16	10	10	9	15	17	16	10	12
HCO_3^-	15		17	16	10	10	9	15	17	16	10	12
$CO_3^=$	0		0	0	0	0	0	0	0	0	0	0
Tot. Hard	17		22	31	10	10	9	15	15	14	9	10
Car Hard.	15		17	16	10	10	9	15	15	14	9	10
N. C. H.	2		5	15	0	0	0	0	0	0	0	0
Sulfates	10.9		10	--	3.0	1.2	1.9	1.5	2.2	2.6	2.9	5.5
Color	10		8	100	20	8	5	4	4	8	9	14
Turbid.	9		4	150	12	10	6	19	3	7	11	18
Iron	0.05		0.01 [3]	--	--	0.10	--	0.04	0.12	0.06	0.02	0.00
Copper	0.005		0.000	--	--	0.000	--	0.000	0.000	0.000	0.000	0.000
Zinc	--		--	--	--	--	--	--	--	--	--	--
Lead	--		--	--	--	--	--	--	--	--	--	--
Aluminum	0.11		0.05	--	--	0.01	--	0.04	0.00	0.03	0.07	0.10
Calcium	5.5		4.1	--	--	1.5	--	3.6	4.8	3.5	1.3	2.0
Magnes.	1.1		1.4	--	--	0.4	--	1.2	1.0	0.8	0.6	0.8
Sodium	2.1		0.3	--	--	1.5	--	2.0	2.0	1.5	0.5	2.0
Potass.	1.5		1.5	--	--	1.2	--	2.0	2.0	0.4	2.4	0.3
Mangan.	--		--	--	--	--	--	--	--	--	--	--
Silver	--		--	--	--	--	--	--	--	--	--	--
Tot.Sol.	48		42	89	130	58	39	30	30	32	83	57
Conduct.	52		39	38	22	18	26	34	38	38	29	27

& D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

* - At Leavenworth

1 - 1955, 2 - 1956, 3 - 1957

4 - Avg. Monthly at Plain

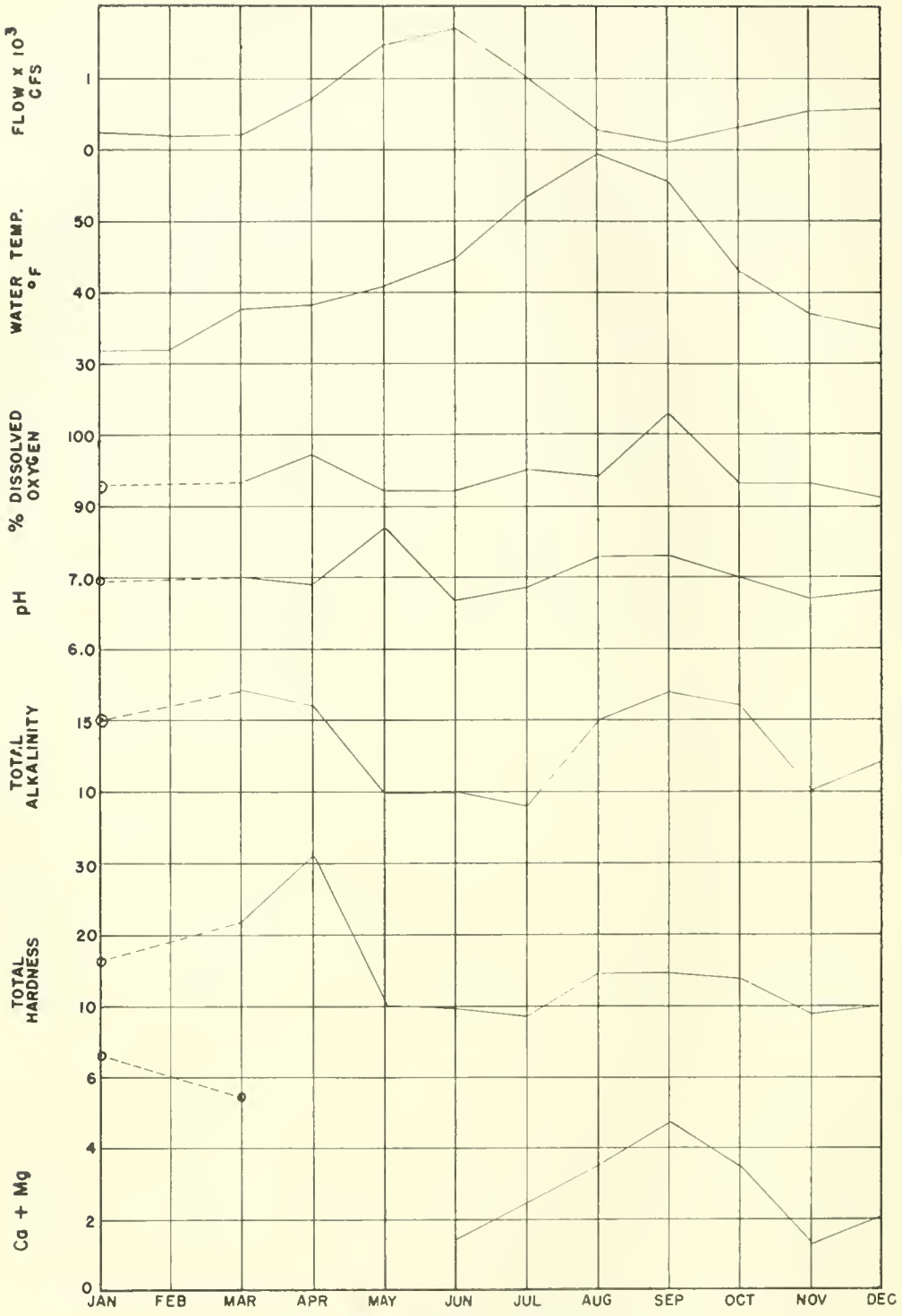
Table 16.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

Sta.: Nason Creek Sta. No.: -- Designation: --

Summary Period: U.S.F. & W.S. 1940 Data

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year												
Samples				1	6	3		1		1	1	
CFS 10^3												
Water °F				50	42.8	45.5		61		47	38.5	
Air °F												
Dis. Oxy.				10.8	10.8	11.0		10		10.9	12.2	
% Satur.				96	87	92		100		93	92	
Car. Di.				2.4	1.8	2.1		1.8		1.8	2.0	
pH				--	6.9	6.9		7.1		6.9	7.0	
Ammonia												
Total Alk				50(?)	11	13		22		16	11	
HCO_3^-				50(?)	11	13		22		16	11	
$CO_3^=$				0	0	0		0		0	0	
Tot. Hard												
Car Hard.												
N. C. H.												
Sulfates												
Color												
Turbid.												
Iron												
Copper												
Zinc												
Lead												
Aluminum												
Calcium												
Magnes.												
Sodium												
Potass.												
Mangan.												
Silver												
Tot.Sol.												
Conduct.												

* D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

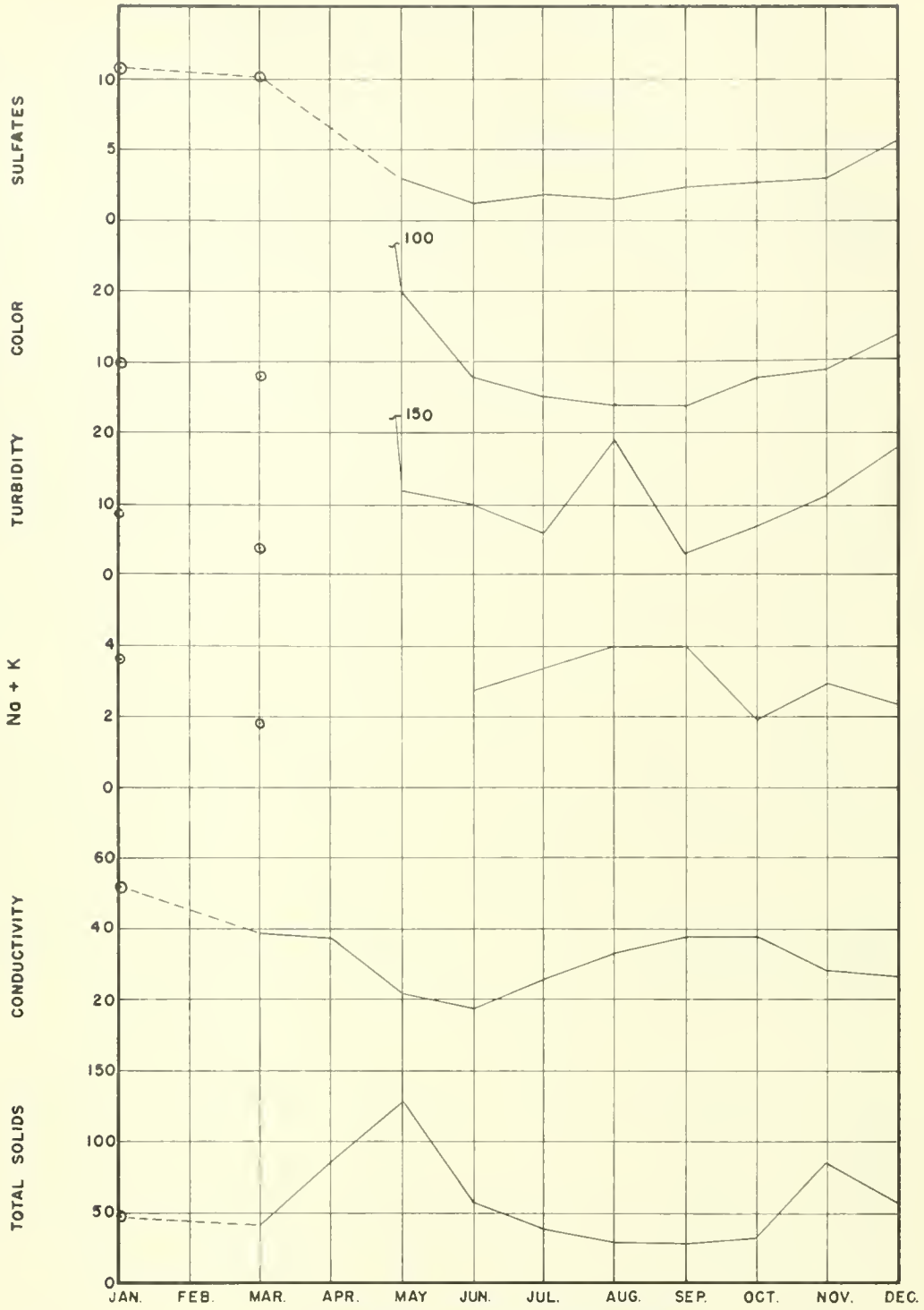


NASON CREEK NEAR MOUTH

Average Monthly Water Quality

1955 - 1957

FIG. 25



NASON CREEK NEAR MOUTH

Average Monthly Water Quality

1955 – 1957

FIG. 26

Table 17.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

Sta: Chiwawa River (Near Mouth) Sta. No.: 44 Designation: CWC - 524

Summary Period: June 1955 - March 1957

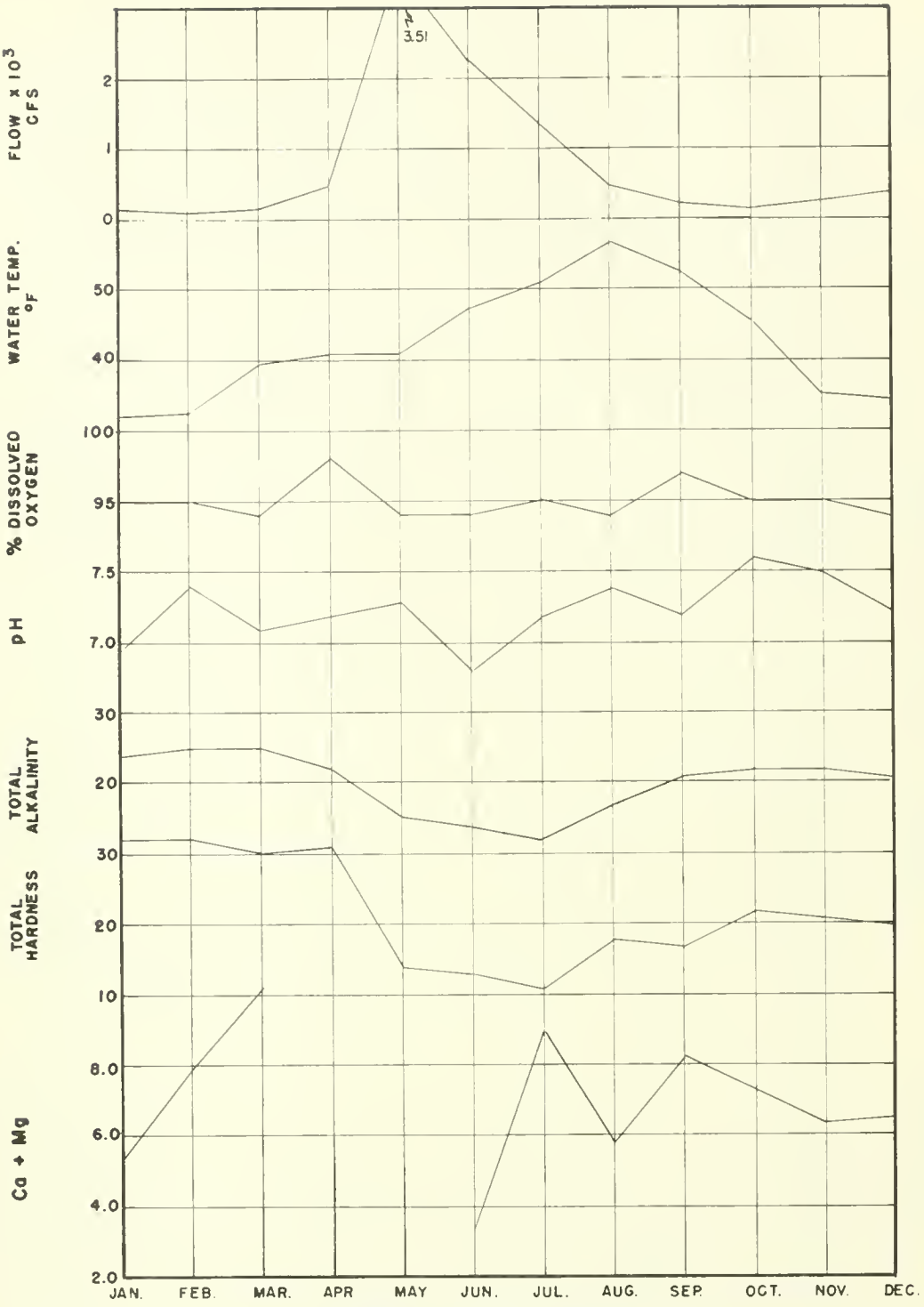
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	2,3	2,3	2,3	2	2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Samples	2	2	2	1	1	2	5	4	4	4	3	2
CFS 10^3	0.15	0.11	0.15	0.19	3.51	2.26	1.37	0.47	0.21	0.13	0.24	0.38
Water °F	32.0	32.3	39.3	41.0	41.0	47.3	50.9	56.6	52.3	45.3	35.1	34.4
Air °F[4]	18.2	24.6	36.2*	47.2	58.1	56.8	64.8	64.2	56.4	44.0	31.5	25.1
Dis. Oxy.	13.5	13.4	12.3	11.8	12.0	10.8	10.5	9.5	10.3	10.9	13.0	12.7
% Satur.	93	92	94	91	93	93	94	91	94	89	94	90
Car. Di.	1.2	3.7	2	2.0	1.5	1.7	1.7	1.6	1.4	1.6	1.2	1.2
ph	6.95	7.4	7.1	7.2	7.3	6.8	7.19	7.4	7.2	7.6	7.5	7.22
Ammonia	0.11	0.10	0.1	0.18	0.06	0.04	0.08	0.15	0.15	0.13	0.09	0.09
Total Alk	24	25	25	22	15	14	12	17	21	22	22	21
HCO_3^-	24	25	25	22	15	14	12	17	21	22	22	21
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot. Hard	32	32	30	31	14	13	11	18	17	22	21	20
Car Hard.	24	25	25	22	14	13	11	17	17	22	21	20
N. C. H.	8	7	5	9	0	0	0	1	0	0	0	0
Sulfates	5.0	3.7	2.7	2.3	2.4	1.0	2.0	1.5	2.6	3.0	3.1	5.1
Color	8	8	10	12	20	11	5	5	4	8	6	10
Turbid.	9	3	6	4	25	14	5	16	9	8	7	7
Iron	0.03	0.22	0.01	--	--	0.00	0.01	0.04	0.01	--	0.00	0.01
Copper	0.000	0.016	0.000	--	--	0.30	0.000	0.000	0.000	--	0.000	0.000
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	0.02	0.00	0.06	--	--	0.02	0.02	0.01	0.00	--	0.03	0.01
Calcium	4.0	6.8	9.2	--	--	2.5	9.0	4.8	7.5	--	5.0	5.0
Magnes.	1.4	1.2	1.2	--	--	0.9	0.1	1.0	0.8	--	1.4	1.6
Sodium	1.7	1.0	0.8	--	--	1.0	3.0	1.5	2.0	--	0.5	1.0
Potass.	1.3	0.5	1.0	--	--	0.8	2.0	1.2	1.6	--	2.0	0.4
Mangan.	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	57	107	30	13	188	60	50	45	43	36	69	52
Conduct.	59	57	57	55	32	28	31	36	46	51	47	48

% D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

* At Leavenworth

1 - 1955, 2 - 1956 3 - 1957

4 - Avg. Monthly at Plain

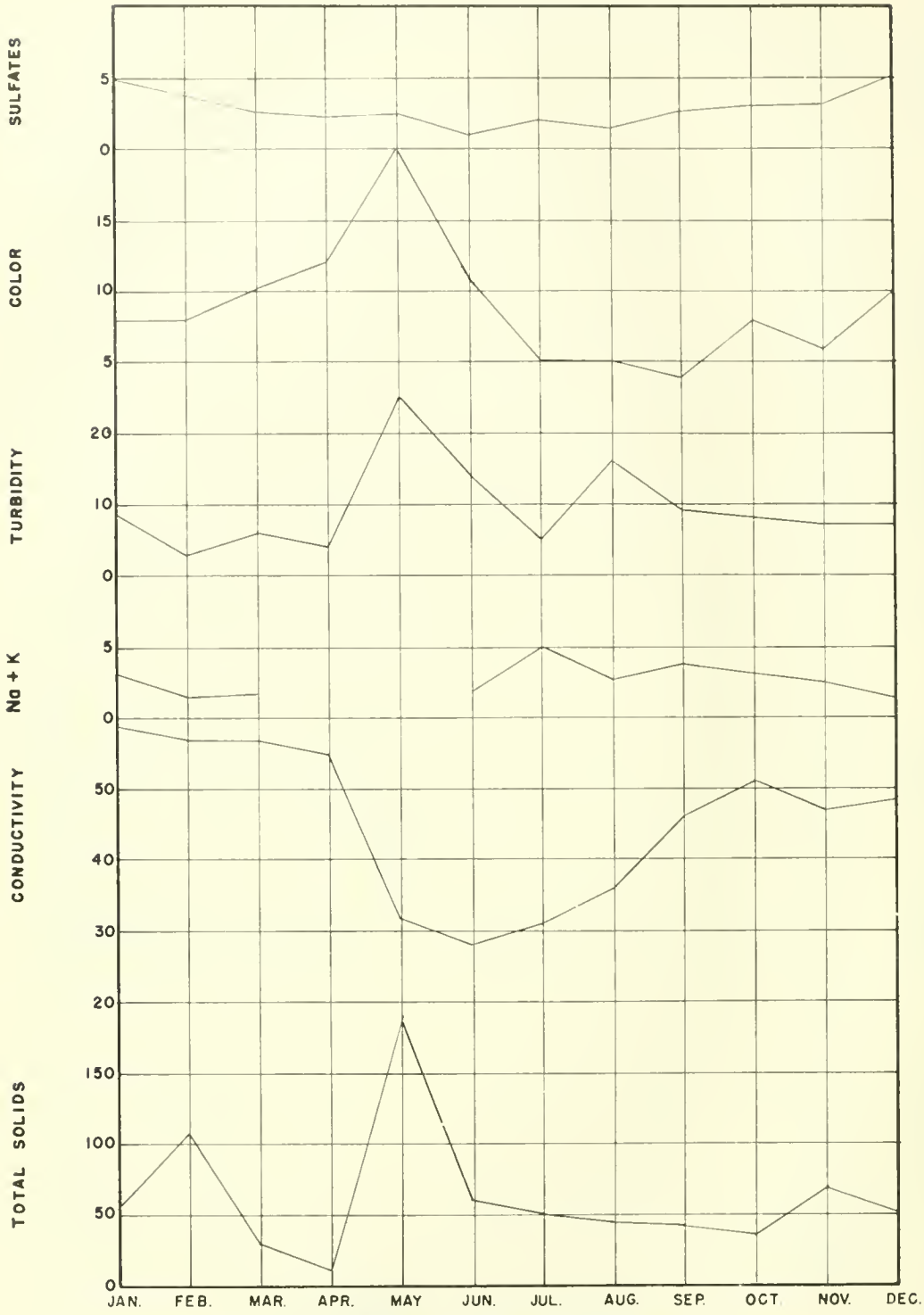


CHIWAWA RIVER NEAR MOUTH

Average Monthly Water Quality

1955 - 1957

FIG. 27



CHIWAWA RIVER NEAR MOUTH

Average Monthly Water Quality

1955 - 1957

FIG. 28

Table 18.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

Sta: Wenatchee River (Below Plain) Sta. No.: 45 Designation: CW - 514

Summary Period: June 1955 to March 1957

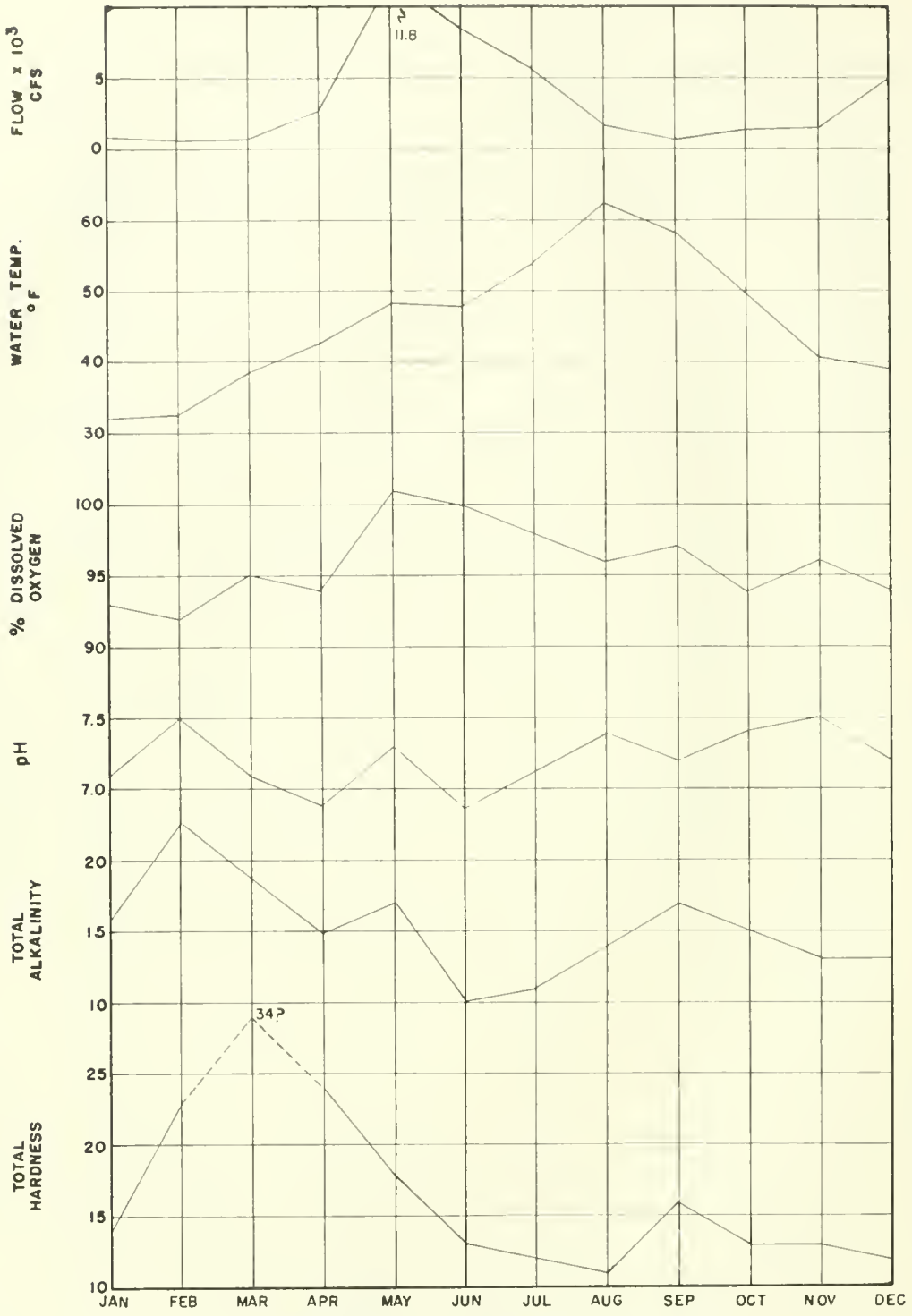
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	3	3	2,3	2	2	1,2	1,2	1,2	1,2	1,2	2	2
Samples	1	1	2	1	1	2	5	4	4	3	2	1
CFS 10^3	0.95	0.80	0.74	2.70	11.80	8.40	5.70	1.90	0.82	1.40	1.40	4.90
Water °F	32.0	32.4	38.6	42.8	48.2	48.0	54.0	62.1	58.2	49.7	40.9	39.2
Air °F[4]	12.9	28.0	36.2*	47.2	58.1	56.8	64.8	64.2	56.4	44.0	31.5	25.1
Dis. Oxy.	13.7	13.2	12.6	11.7	11.7	11.0	10.3	9.1	9.6	10.5	12.2	12.3
% Satur.	94	92	95	94	101	94	96	93	94	93	95	94
Car. Di.	2.0	6.5	2	2.0	2.5	1.6	1.7	1.8	1.2	1.5	1.8	1.0
pH	7.1	7.5	7.1	6.9	7.3	6.86	7.1	7.4	7.2	7.41	7.5	7.2
Ammonia	T	T	0.1	0.21	0.02	0.07	0.10	0.19	0.09	0.09	0.01	0.01
Total Alk	16	23	19	15	17	10	11	14	17	15	13	13
HCO_3^-	16	23	19	15	17	10	11	14	17	15	13	13
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot. Hard	14	23	34	24	18	13	12	11	16	13	13	12
Car hard.	14	23	19	15	17	10	11	11	16	13	13	12
N. C. H.	0	0	15	9	1	3	1	0	0	0	0	0
Sulfates	5.0	2.9	2.8	5.0	2.4	1.5	1.8	1.5	1.6	2.6	2.6	5.5
Color	6	5	8	45	40	5	5	5	4	9	5	12
Turbid.	18	5	4	40	16	13	4	12	4	7	7	15
Iron	--	--	--	--	--	--	--	--	--	--	--	--
Copper	--	--	--	--	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--	--	--	--	--
Calcium	--	--	--	--	--	--	--	--	--	--	--	--
Magnes.	--	--	--	--	--	--	--	--	--	--	--	--
Sodium	--	--	--	--	--	--	--	--	--	--	--	--
Potass.	--	--	--	--	--	--	--	--	--	--	--	--
Mangan.	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	59	83	41	37	130	42	39	36	38	27	78	59
Conduct.	26	63.5	43	36	29	25	24	31	33	32	37	26

% D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.

* At Leavenworth

1 - 1955 2 - 1956 3 - 1957

4 - Avg. Monthly at Plain

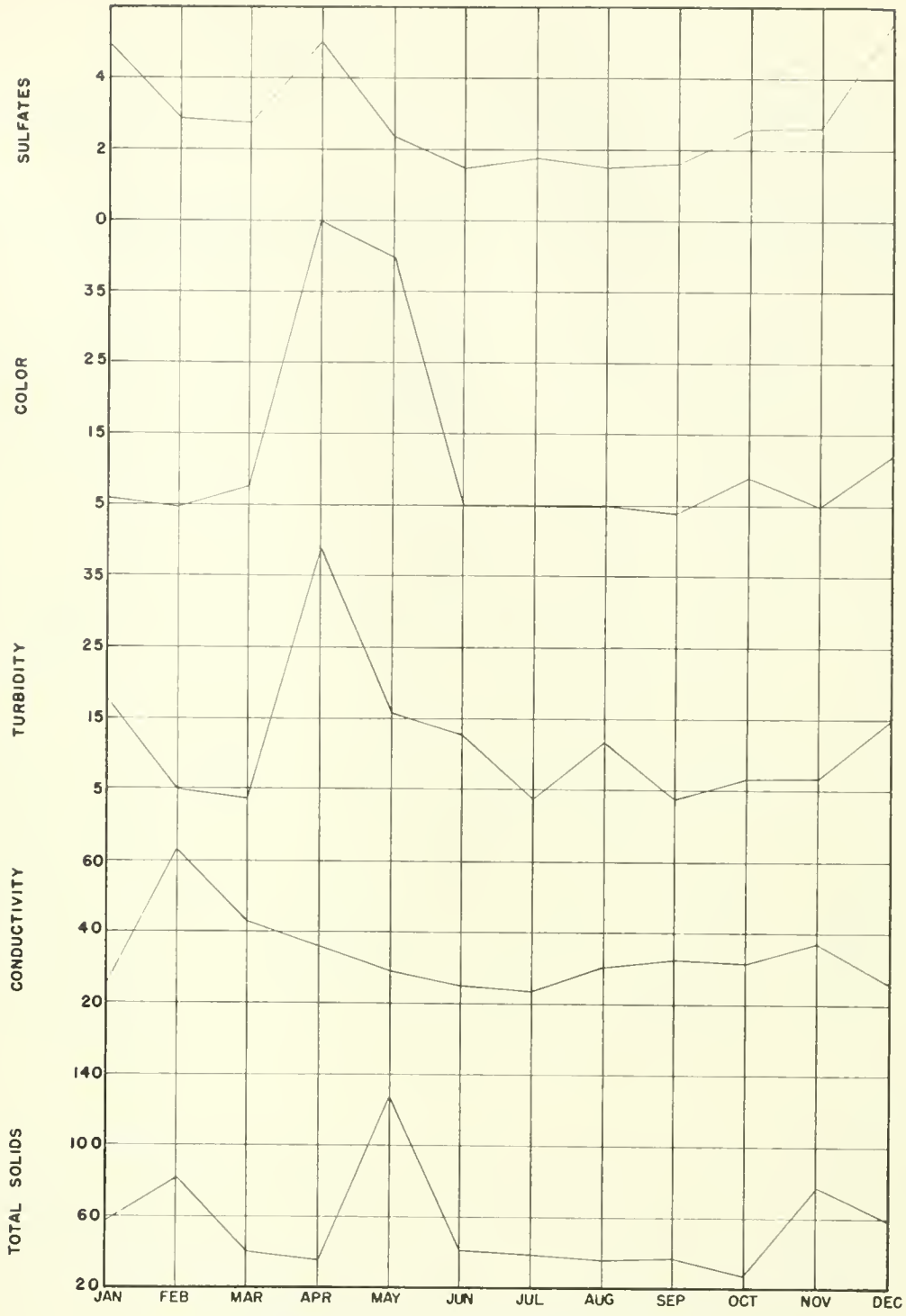


WENATCHEE RIVER BELOW PLAIN

Average Monthly Water Quality

1955 - 1957

FIG. 29



WENATCHEE RIVER BELOW PLAIN

Average Monthly Water Quality

1955 - 1957

FIG. 30

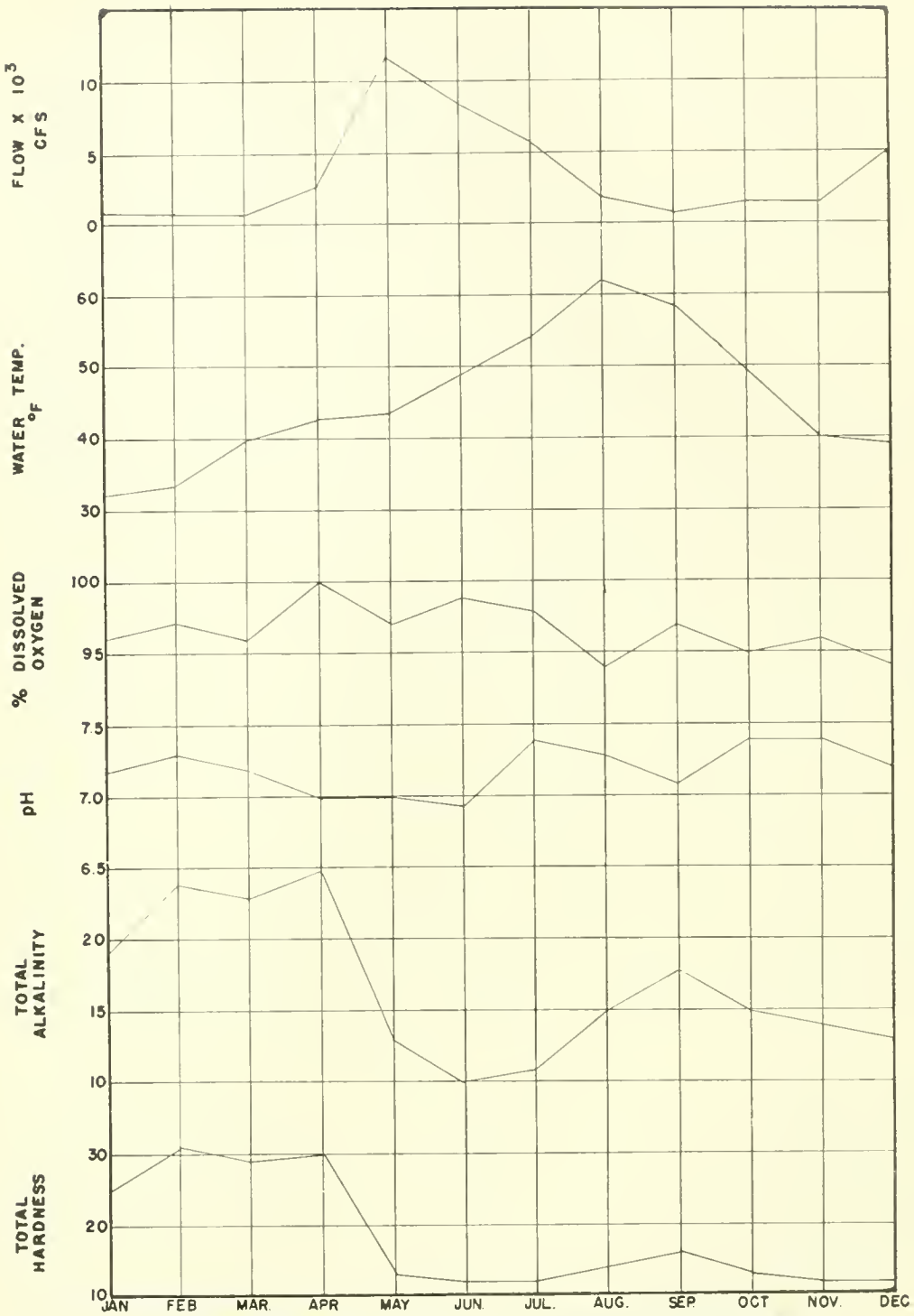
Table 19.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

Sta: Wenatchee River (Tumwater Canyon) Sta. No.: 46 Designation: CW 503

Summary Period: June 1955 to March 1957

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	2,3	2,3	2,3	2	2	1,2	1,2	1,2	1,2	1,2	2	2
Samples	2	2	2	1	1	2	5	4	4	3	2	1
CFS 10^3	0.95	0.80	0.74	2.70	11.80	8.40	5.70	1.90	0.82	1.40	1.40	4.90
Water °F	32.0	33.1	39.6	42.8	43.7	48.9	54.6	62 1	58.8	49.4	40.7	39.2
Air °F4	18.6	24.4	36.2	47.8	59.7	61.7	68.6	67.9	60.2	47.4	33.6	28.7
Dis. Oxy.	13.5	13.5	12.6	11.8	11.9	11.0	10.2	9.0	9.6	10.6	12.8	12.4
% Satur.	92	94	97	98	97	96	96	92	95	93	99	95
Car. Di.	1.5	3.7	2	2.0	2.0	1.8	2.1	1.6	1.1	1.5	1.7	1.5
pH	7.17	7.3	7.2	7.0	7.0	6.94	7.4	7.3	7.1	7.4	7.4	7.2
Ammonia	0.15	0.10	0.1	0.25	T	0.05	0.12	0.21	0.10	0.09	0.01	0.01
Total Alk	19	24	23	25	13	10	11	15	18	15	14	13
HCO_3^-	19	24	23	25	13	10	11	15	18	15	14	13
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot. Hard	25	31	29	30	13	12	12	14	16	13	12	12
Car Hard.	17	24	23	25	13	10	11	14	16	13	12	12
N. C. H.	8	7	6	5	0	2	1	0	0	0	0	0
Sulfates	3.0	2.8	3.0	3.0	5.9?	1.4	2.0	1.5	1.8	2.8	2.5	4.5
Color	8	8	10	38	17	8	5	6	4	8	5	12
Turbid.	10	3 (2)	12	33	22	12	6	11	5	7	9	15
Iron	0.05	--	--	--	--	--	--	--	--	--	--	--
Copper	0.000	--	--	--	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	0.24	--	--	--	--	--	--	--	--	--	--	--
Calcium	14.0	--	--	--	--	--	--	--	--	--	--	--
Magnes.	1.0	--	--	--	--	--	--	--	--	--	--	--
Sodium	0.5	--	--	--	--	--	--	--	--	--	--	--
Potass.	1.2	--	--	--	--	--	--	--	--	--	--	--
Mangan.	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	43	76	42	95	175(?)	49	40	38	29	17	71	41
Conduct.	40	58	46	54	35	30	26	29	33	32	37	25

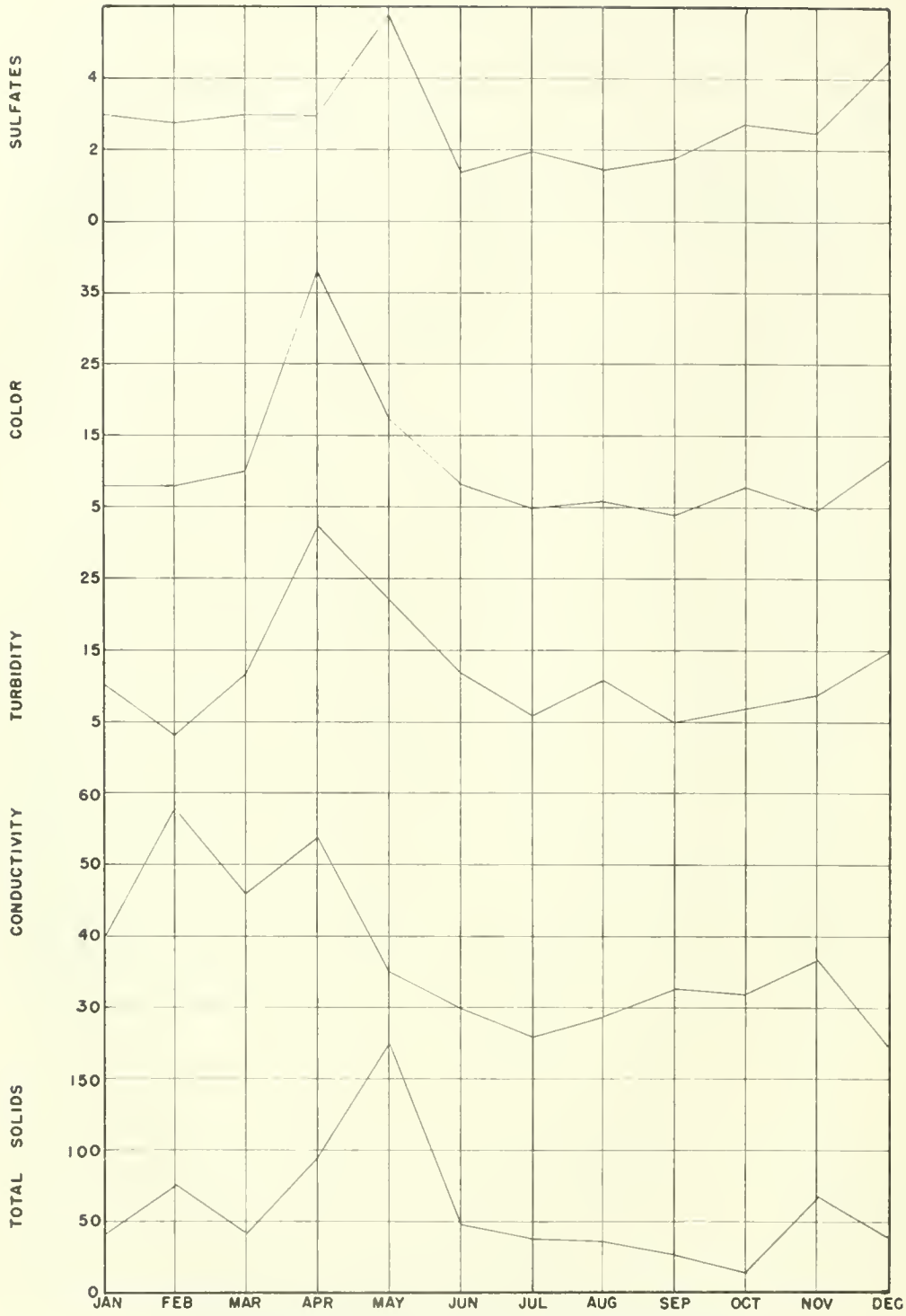
/ D. O. satur. is at sea level: alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.
1 - 1955 2 - 1956 3 - 1957
4 - Avg. Monthly at Leavenworth



WENATCHEE RIVER AT TUMWATER CANYON

Average Monthly Water Quality
1955 - 1957

FIG. 31



WENATCHEE RIVER AT TUMWATER CANYON

Average Monthly Water Quality

1955 - 1957

FIG. 32

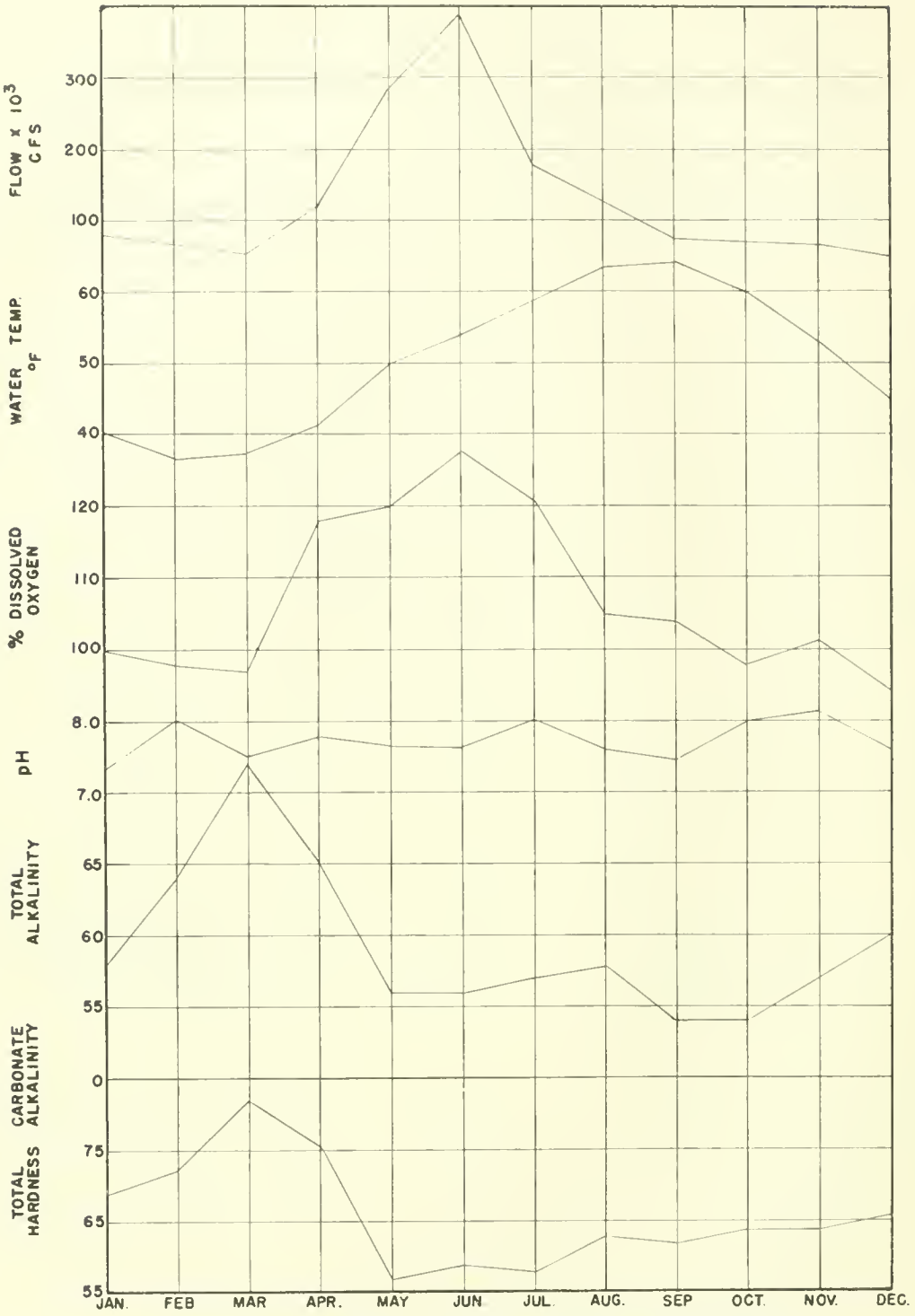
Table 20.--Water quality summary - monthly average.
[Chemical characteristics in mg./liter where applicable]

Sta: Columbia R. at Beebe Orchard Bridge Sta. No.: 47 Designation: C 504

Summary Period: April 1956 - January 1957

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Year	2	2	2	1	1	1	1	1	1	1	1	1
Samples	1	1	1	1	1	1	2	3	2	2	2	1
CFS 10^3	80	69	56	119	285	387	178	126	73	72	65	56
Water °F	40.5	36.5	37.4	41.2	50.0	53.9	58.6	63.4	64.1	60.0	53.0	45.0
Air °F [3]	16.0	27.2	39.3	51.7	62.1	62.6	74.1	72.2	63.2	50.6	35.5	31.4
Dis. Oxy.	12.9	13.3	13.1	14.9	13.6	13.8	12.4	10.2	9.9	9.9	10.9	11.4
% Satur.	100	98	97	118	120	128	121	105	104	98	101	94
Car. Di.	2.5	6.5	3.0	2.0	2.0	2.0	2.2	2.0	2.0	2.0	1.7	1.5
pH	7.35	8.01	7.5	7.8	7.65	7.63	8.02	7.6	7.47	8.0	8.1	7.6
Ammonia	T	T	T	0.24	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total Alk	58	64	72	65	56	56	57	58	54	54	57	60
HCO_3^-	58	64	72	65	56	56	57	58	54	54	57	60
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot. Hard	69	72	82	76	57	59	58	63	62	64	64	66
Car Hard.	58	64	72	65	56	56	57	58	54	54	57	60
N. C. H.	11	8	10	11	1	3	1	5	8	10	7	6
Sulfates	11.5	12	9	17	14	10	12	8	8	8.5	10.2	15
Color	5	5	17	15	22	10	5	2	4	9	4	8
Turbid.	13	2	45	12	26	20	9	15	9	10	5	10
Iron	0.02	0.04	0.00	--	--	0 02	--	0.02	0.02	0.03	0.00	0.01
Copper	0.000	0.020	0.000	--	--	0.016	--	0.000	0.020	0.000	0.000	0.000
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	0.12	0.04	0.06	--	--	0.03	--	0.00	0.00	0.02	0.03	0.00
Calcium	11.0	22.0	24.4	--	--	13.0	--	19.0	22.4	22.9	12.0	12.0
Magnes.	6.0	4.0	5.6	--	--	8.0	--	4.0	3.4	3.6	4.6	1.8
Sodium	3.0	2.0	2.0	--	--	2.0	--	1 5	1.5	3.5	1.5	2.5
Potass.	1.0	0.8	1.3	--	--	0.8	--	1.2	1.0	1.5	2.0	0.8
Mangan.	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	68	95	151	95	135	109	69	80	68	54	119	87
Conduct.	139	152	152	157	113	111	131	126	127	121	137	134

% D. O. satur. is at sea level; alkalinity and hardness as equivalent $CaCO_3$; conductivity in micromhos per cm. at 25 °C.
1 - 1956 2 - 1957
3 - Avg. Monthly at Lakeside

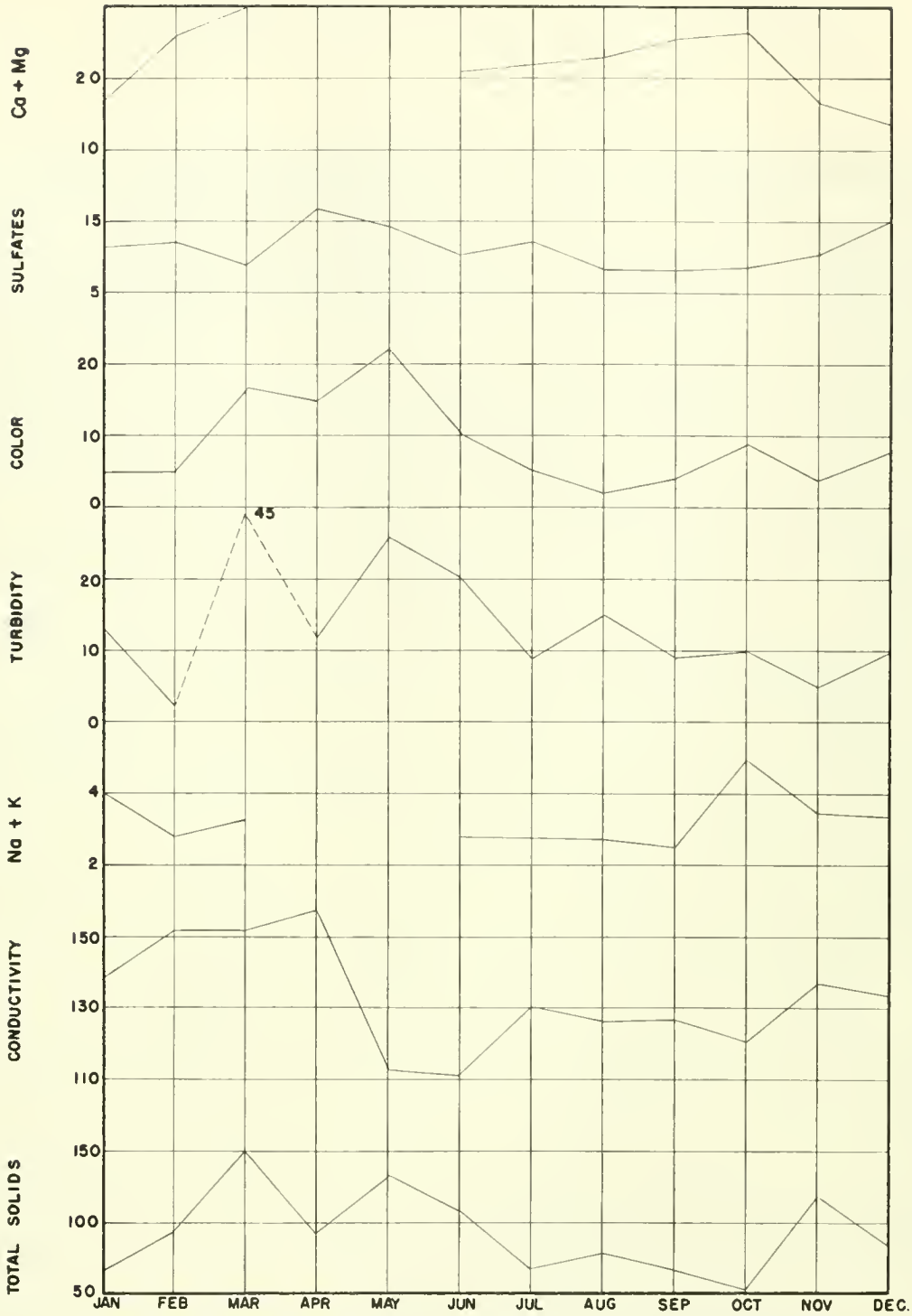


COLUMBIA RIVER AT BEEBE ORCHARD BRIDGE

Average Monthly Water Quality

1956 - 1957

FIG. 33



COLUMBIA RIVER AT BEEBE ORCHARD BRIDGE

Average Monthly Water Quality

1956 - 1957

FIG. 34

Table 21.--Lake Wenatchee water quality summary.
[Chemical characteristics in mg./liter where applicable]

June 1955 to February 1957

Date	6/27/55		7/12/55		7/26/55			8/9/55		
Sample Depth Ft.	10	135	10	80	10	50	150	10	75	175
Water Temp. °F	45.8	43.9	49.0	46.0	50.4	50.1	47.4	55.4	50.5	46.8
Air Temp. °F [1]	57		69		57			64		
Diss. Oxygen	11.0	11.0	10.8	10.8	10.7	10.5	10.8	10.0	9.95	10.05
% D. O. Satur.	92	90	94	90	95	93	92	95	88	85
Carbon Dioxide	1.5	2.0	1.5	2.0	1	1	1	1	1	1.5
pH	6.9	6.8	6.9	6.7	6.65	6.95	6.70	7.3	7.2	7.1
Total Alk. $CaCO_3$	12	10	9	9	9	10	10	10	11	11
HCO_3^-	12	10	9	9	9	10	10	10	11	11
$CO_3^=$	0	0	0	0	0	0	0	0	0	0
Total Hard $CaCO_3$	10	12	21	26	12	15	12	19	18	19
Carb Hard. $CaCO_3$	10	10	9	9	9	10	10	10	11	11
Non-Carb. Hard.	0	2	12	17	3	5	2	9	7	8
Sulfates $SO_4^=$	T	T	3	4	1.5	1.5	1	0.8	1.4	2.7
Color	10	10	5	5	7	6	6	5	6	6
Turbidity	2	2	4	5	4	4	8	2	4	3
Total Iron	--	--	--	--	--	--	--	0.01	--	--
Copper	--	--	--	--	--	--	--	0.00	--	--
Zinc	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	0.01	--	--
Calcium	--	--	--	--	--	--	--	--	--	--
Magnesium	--	--	--	--	--	--	--	1.4	--	--
Sodium	--	--	--	--	--	--	--	1.0	--	--
Potassium	--	--	--	--	--	--	--	1.0	--	--
Manganese	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--
Total Solids	17	41	--	--	43	41	51	10	6	9
Cond. umhos 25°	22	21	24	24	22	19	19	21	21	23

1 - Avg. for day at Plain

Table 21 - cont'd.

Date	8/25/55			9/7/55			9/21/55				10/1/55
Sample Depth Ft.	15	75	140	10	75	175	10	60	120	170	10[1]
Water Temp. °F.	55.9	--	--	59.4	50.0	--	56.0	55.5	48.4	47.0	56.1
Air Temp. °F.[2]	57			67			47				48
Diss. Oxygen	9.9	9.9	9.4	9.75	9.85	10.0	9.7	9.7	9.6	9.45	9.65
% D.O. Satur.	93	--	--	90	84	--	92	92	83	80	98
Carbon Dioxide	1.5	1.5	1.5	0.5	1.5	2.5	1	1	2	3	--
pH	7.6	7.5	7.3*	6.9	6.7	6.6	7.35	7.32	6.95	6.90	7.4
Tot. Alk. $CaCO_3$	11	10	12	16	12	15	10	10.5	9.5	9.5	11.5
$HCO_3^=$	11	10	12	16	12	15	10	10.5	9.5	9.5	11.5
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0
Tot. Hrd. $CaCO_3$	16	12	16	24	26	28	12	10.5	10.5	10	11
Carb. Hrd. $CaCO_3$	11	10	12	16	12	15	10	10.5	9.5	9.5	11
Non-Carb. Hard.	5	2	4	8	14	13	2	0	1	0.5	0
Sulfates $SO_4^=$	1.5	1.5	1.5	1.5	2	1.5	1	1.5	1.7	1.7	2.2
Color	10	8	8	8	8	8	3	4	3	3	5
Turbidity	4	6	6	7	9	7	2	2	2	2	3
Total Iron	--	--	--	--	--	--	0.05	--	--	--	--
Copper	--	--	--	--	--	--	0.000	--	--	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	0.02	--	--	--	--
Calcium	--	--	--	--	--	--	12.0	--	--	--	--
Magnesium	--	--	--	--	--	--	0.2	--	--	--	--
Sodium	--	--	--	--	--	--	1.0	--	--	--	--
Potassium	--	--	--	--	--	--	1.2	--	--	--	--
Manganese	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--
Total Solids	50	42	49	19	28	31	45	42	46	42	29
Cond. umhos 25°	26	24	27	22	22	22	23	22	22	23	23

* - pH Values doubtful
1 - Near outlet
2 - Avg. for day at Plain

Table 21 - cont'd.

Date	10/23/55			Lake inaccessible until May because of snow and ice	4/14/56	5/19/56			6/20/56		
Samples	10	75	175		2[1]	10	75	175	10	75	125
Water °F	51.5	50.3	46.1		35.8	42.1	40.8	40.6	43.5	42.6	42.1
Air °F [2]	44										
Dis. Oxy.	9.5	9.3	8.7		10.65	13.0	13.0	14.0	11.3	11.3	11.4
% Satur.	86	82	73		77	102	101	108	92	91	90
Car. Di.	1.5	1.0	1.0		2	2	2	1.5	2	2	2
pH	7.1	7.1	6.8		6.3	6.7	6.9	6.9	6.6	6.6	6.7
Total Alk.	11	10	10.5		10	13	14	14	10	10	10
HCO_3^-	11	10	10.5		10	13	14	14	10	10	10
$CO_3^=$	0	0	0		0	0	0	0	0	0	0
Tot. Hard.	10	10	10		21	13	14	14	8	8	7
Car. Hard.	10	10	10		10	13	14	14	8	8	7
Non-Car.H.	0	0	0		11	0	0	0	0	0	0
Sulfates	1.7	2.0	1.9		2	3.1	5.1	5.2	3.0	1.9	2.7
Color	5	5	10		5	20	20	20	5	5	5
Turbidity	2	4	2		2	10	9	11	10	10	5
Total Iron	--	--	--		--	--	--	--	0.16	--	--
Copper	--	--	--		--	--	--	--	0.040	--	--
Zinc	--	--	--		--	--	--	--	--	--	--
Lead	--	--	--		--	--	--	--	--	--	--
Aluminum	--	--	--		--	--	--	--	0.15	--	--
Calcium	--	--	--		--	--	--	--	1.5	--	--
Magnesium	--	--	--		--	--	--	--	0.6	--	--
Sodium	--	--	--		--	--	--	--	1.0	--	--
Potassium	--	--	--		--	--	--	--	0.8	--	--
Manganese	--	--	--		--	--	--	--	--	--	--
Silver	--	--	--		--	--	--	--	--	--	--
Total Sol.	19	25	27		--	79	56	46	59	58	45
Conduct.	24.8	27.6	22.9		28.4	30	30	29	25	21	21

1 - Collected at outlet
2 - Avg. for day at Plain

Table 21 - cont'd.

Date	7/5/56			7/18/56			8/1/56			8/17/56		
Samples	10	75	125	10	75	175	10	75	150	10	75	175
Water °F	47.2	45.1	43.8	51.2	46.2	44.1	50.4	48.8	47.0	58.4	52.3	46.8
Dis.Oxy.	11.0	11.0	11.1	10.7	10.8	10.7	10.2	10.4	10.5	9.7	9.8	9.9
% Satur.	93	91	90	96	91	88	91	90	90	95	89	84
Car.Di.	2	2	1.5	2	2.5	2.5	2.5	3	2	1.5	2.5	3.5
pH	6.6	6.6	6.7	6.5	6.7	6.7	6.4	6.6	6.6	7.2	7.0	7.0
Tot.Alk.	10	10	10	8	8	8	9	9	9	9	10	10
HCO_3^-	10	10	10	8	8	8	9	9	9	9	10	10
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot.Hard.	9	9	9	6	7	6	8	8	8	7	8	10
Car.Hrd.	9	9	9	6	7	6	8	8	8	7	8	10
N. C. H.	0	0	0	0	0	0	0	0	0	0	0	0
Sulfates	1.5	1.2	1.8	1.4	1.4	2.0	2.5	2.1	2.1	2	5	2
Color	4	4	4	4	4	4	3	3	3	2	2	2
Turbidity	5	5	5	5	4	5	12	13	13	19	16	16
Tot.Iron	--	--	--	--	--	--	--	--	--	0.01	--	--
Copper	--	--	--	--	--	--	--	--	--	0.000	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--	--	0.04	--	--
Calcium	--	--	--	--	--	--	--	--	--	2.6	--	--
Magnes.	--	--	--	--	--	--	--	--	--	0.6	--	--
Sodium	--	--	--	--	--	--	--	--	--	1.5	--	--
Pot.	--	--	--	--	--	--	--	--	--	1.2	--	--
Mangan.	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	45	32	31	40	92	80	20	23	25	31	14	10
Cond.	25	25	25	20	20	20	19	19	19	23.7	24.3	21.9

Table 21 - cont'd.

Date	8/29/56		9/12/56			9/25/56		10/10/56			10/24/56	
Samples	10	75	10	75	175	10	75	10	75	150	10	100
Water °F	55.5	51.5	58.1	50.5	43.0	56.7	51.1	54.0	51.8	45.1	50.0	46.0
Dis.Oxy.	9.5	10.0	9.3	9.3	9.4	9.9	9.6	9.9	9.6	9.4	9.9	9.2
% Satur.	90	90	91	82	76	94	86	92	87	78	88	78
Car.Di.	2	2.5	1.5	2	5	1.5	3.5	1	2	3	1	2
pH	6.9	6.8	7.1	6.8	6.6	6.7	6.3	7.2	7.0	6.8	6.9	6.6
Tot.Alk.	8	8	10	9	9	12	12	10	10	10	12	9
HCO_3^-	8	8	10	9	9	12	12	10	10	10	12	9
$CO_3^=$	0	0	0	0	0	0	0	0	0	0	0	0
Tot.Hard.	7	8	8	7	7	10	11	8	8	8	8	6
Car.Hard.	7	8	8	7	7	10	11	8	8	8	8	6
N. C. H.	0	0	0	0	0	0	0	0	0	0	0	0
Sulfates	2.9	2.9	1.6	2.0	1.9	1.5	1.5	2.1	2.5	1.9	1.9	2.6
Color	0	0	2	2	2	3	3	7	7	7	8	9
Turbidity	4	3	5	6	6	4	3	20	21	19	5	5
Tot.Iron	0.00	--	--	--	--	--	--	--	--	--	--	--
Copper	0.000	--	--	--	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	0.00	--	--	--	--	--	--	--	--	--	--	--
Calcium	0.8	--	--	--	--	--	--	--	--	--	--	--
Magnesium	0.2	--	--	--	--	--	--	--	--	--	--	--
Sodium	0.3	--	--	--	--	--	--	--	--	--	--	--
Potassium	2.0	--	--	--	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--	--	--	--	--
Tot.Sol.	21	21	23	21	15	16	12	17	23	19	12	10
Conduct.	21	19	21.6	19.6	19.6	23	21	23	23	21	21.5	20.5

Table 21 - cont'd.

Date	11/7/56[1]		11/21/56		12/19/56			2/12/57
Sample Depth Ft.	10	75	10	150	10	150		4
Water Temp. °F	47.0	46.4	44.6	43.9	41.8	40.4		32.4
Diss. Oxygen	10.1	10.0	10.6	10.6	11.0	11.0		12.3
% D. O. Satur.	87	78	87	86	87	85		85
Carbon Dioxide	1.5	2	1	1	1	1		6.5
pH	7.0	6.9	6.9	6.9	6.8	6.8		7.0
Total Alk. $CaCO_3$	10	10	12	11	10	9		17
HCO_3^-	10	10	12	11	10	9		17
$CO_3^=$	0	0	0	0	0	0		0
Total Hard $CaCO_3$	9	8	7	7	8	8		14
Carb Hard. $CaCO_3$	9	8	7	7	8	8		14
Non-Carb. Hard.	0	0	0	0	0	0		0
Sulfates $SO_4^=$	2.5	3	3	3	1.9	2.1		2.4
Color	5	5	10	10	7	7		5
Turbidity	4	4	5	7	4	4		9
Total Iron	--	--	--	--	--	0.03		0.00
Copper	--	--	--	--	--	0.000		0.010
Zinc	--	--	--	--	--	--		--
Lead	--	--	--	--	--	--		--
Aluminum	--	--	--	--	--	0.00		0.01
Calcium	--	--	--	--	--	0.5		3.8
Magnesium	--	--	--	--	--	0.8		1.6
Sodium	--	--	--	--	--	2.0		1.0
Potassium	--	--	--	--	--	0.1		1.0
Manganese	--	--	--	--	--	--		--
Silver	--	--	--	--	--	--		--
Total Solids	87	90	38	39	28	--		48
Cond. umhos 25°	22	22	22	22	22	22		45

Lake frozen January to April - Feb. sample taken through hole in ice near outlet

1 - Collected near head of lake

Table 22 - Lake Wenatchee Water Quality Data Collected by U.S. F. & W.S. in 1939

Date	Sta. No.	Depth Feet	Avg. Air. Temp.[1]	Water Temp. °F	D.O. mg/l	% D.O. Satur	CO_2 mg/l	pH	Total Alk. mg/l
9-19-39	1	1	63	60.4	8.9	89	0.8	7.2	8.5
		2		60.3	8.8	89	1.0	7.2	8.5
		100		50.4	8.8	78	3.0	6.7	8.5
		140*		46.4	8.3	70	4.2	6.6	9.0
9-19-39	2	1	63	59.2	8.9	88	1.1	7.3	9.5
		50		57.4	9.0	87	1.7	7.1	9.0
		100		49.8	8.9	79	3.0	6.7	9.0
		150		45.9	8.8	74	3.8	6.7	9.5
		200		45.0	8.5	70	4.0	6.6	9.0
		222*							
10-12-39	2	1	64	57.7	9.5	92	2.0	7.1	9.0
		50		54.7	9.5	89	2.0	7.1	9.0
		100		52.2	9.0	82	3.0	6.9	9.0
		150		46.0	9.1	77	4.0	6.6	8.5
		200		45.0	8.7	72	4.5	6.6	8.5
		220		45.0	8.5	70	5.0	6.6	9.0
10-29-39	2	1	54	52.7	9.6	88	2.0	7.1	8.5
		50		52.0	9.5	86	2.0	7.0	8.5
		100		51.4	9.5	85	2.0	7.0	8.5
		150		46.7	8.5	72	4.5	6.6	8.0
		200		45.3	8.5	71	4.5	6.6	8.5
		220		45.0	7.8	64	5.5	6.6	8.5
9-20-39	3	1	67	60.3	8.9	89	1.3	7.3	9.5
		12*		59.7			1.5	7.2	9.0
9-20-39	4	205*	67	45.0	9.0	75	1.0	7.3	9.5
9-22-39	4	1	70	60.4	9.1	91	1.2	7.2	9.0
		50		57.4	8.9	86	1.5	7.1	9.0
		100		52.2	8.6	78	2.7	6.9	9.5
		150		46.0	9.0	76	3.2	6.7	9.0
		200		45.0	8.8	73	4.0	6.6	8.5
10-27-39	4	1	39	52.3	9.6	87	1.5	7.1	9.0
		50		52.3	9.5	86	2.0	7.1	8.5
		100		51.6	9.7	88	2.0	7.0	8.5
		150		46.2	8.9	75	4.0	6.7	8.0
		205*		45.0	8.0	66	5.0	6.6	8.0
9-24-39	5	1	66	58.3	9.0	88	1.5	7.2	9.0
		50		57.0	8.9	86	2.0	7.1	9.0
		100		54.0	8.7	81	2.5	6.9	8.0
		138*		48.2	8.2	71	4.0	6.6	7.5

* Total depth at station
1 At Leavenworth

Table 22 - cont'd.

Date	Sta. No.	Depth Feet	Avg. Air. Temp.	Water Temp. °F	D.O. mg/l	% D.O. Satur.	CO_2 mg/l	pH	Total Alk. mg/l
11-11-39	5	1	40	49.6	9.8	86	1.3	7.1	7.5
		50		49.5	9.7	85	1.5	7.1	7.5
		100		48.9	9.5	83	2.0	7.1	7.5
		126*		48.9	9.6	83	2.0	7.0	7.0
9-24-39	6	1	66	58.6	9.1	89	1.3	7.2	8.5
		11*		58.3	9.0	88	1.5	7.2	8.5
9-24-39	7	1	66	58.6	9.2	90	1.3	7.2	9.5
		50		57.2	8.9	86	1.5	7.1	9.5
		60*							
10-12-39	8	1	64	57.7	9.5	92	2.0	7.1	9.0
11-11-39	9	1	40	50.0	9.8	87	1.5	7.0	8.0
		50		49.8	9.8	87	2.0	7.1	8.0
		100		49.3	9.8	86	2.0	7.0	7.5
		160*		46.0	7.6	64	5.0	6.5	8.0

Table 23 - Minimum, Weighted Average and Maximum Observed Constituent Values at Station Indicated[1], 1954-1957

	Columbia River McNary Dam			Snake River Near Mouth			Columbia River at Pasco			Yakima River at Enterprise		
	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.
CFS 10^3	85	210	556	19	56	199	60	151	447	1.50	4.8	14.2
Water °F	32.4	50.8	69.4	32.0	52.3	77.2	35.8	51.3	67.3	32.0	53.3	77.2
Dis. Oxy.	7.8	11.2	13.5	7.9	11.2	15.0	9.3	11.9	14.0	7.9	11.1	13.9
% Satur.	84	99	126	91	99	142	88	103	132	83	101	149
Car Di.	0	--	2.7	0	--	2.0	0	--	2.8	0	--	4.2
pH	7.4	7.9	8.9	7.5	8.0	9.1	6.7	7.8	8.6	7.3	7.8	8.9
Total Alk	54	66	89	40	72	161	52	62	75	51	83	163
HCO_3-	54	65	85	40	68	157	52	62	75	51	81	158
CO_3=	0	1	17	0	3	56	0	0	16	0	2	30
Tot. Hard	54	68	107	39	68	160	59	69	91	46	72	134
Car. Hard	54	66	85	39	68	160	52	62	75	46	72	134
N. C. H.	0	3	22	0	0	11	0	6	22	0	0	9
Sulfates	8	15	26	6	25	137	4	11	23	6	12	28
Color	2	18	750	5	28	750	0	10	20	4	22	40
Turbid.	1	20	117	2	55	550	1	12	25	2	33	110
Iron	0.00	0.07	0.45	0.00	0.18	0.40	0.00	[illegible].15	0.00	0.00	[illegible].07	0.30
Copper	0.000	0.01	0.20	0.000	0.028	0.20	0.000	0.004	0.010	0.000	0.025	0.100
Zinc	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.20
Aluminum	0.00	0.07	1.0	0.00	0.02	0.30	0.00	0.02	1.5	0.00	0.03	1.0
Calcium	7	15.1	46.5	9.5	20.7	50	12	17	24	4.2	15	51
Magnes.	0.1	3.2	8.0	0.2	2.3	10.0	0.1	4.1	6.0	0.2	2.8	9.0
Sodium	2.5	7.1	15.0	3.0	16.0	38	0.5	2.0	5.5	1.5	12.5	25.5
Potass.	1.0	1.9	4.7	0.8	2.1	10	0.4	1.1	2.0	0.2	2.5	12
Mangan.	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 23 Cont'd

	Columbia River McNary Dam			Snake River Near Mouth			Columbia River at Pasco			Yakima River at Enterprise		
	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.
Silver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot Sol.	55	133	320	85	219	675	80	110	270	133	221	310
Conduct.	119	159	256	104	193	510	114	142	192	115	194	377

1 Values Weighted According to flow except for water temp. and dissolved oxygen values which are avg. of monthly averages.

* Single observation

Table 23 - Minimum, Weighted Average and Maximum Observed Constituent Values at Station Indicated [1], 1954-1957

	Yakima River Above Thorp			Wenatchee River Near Mouth			Crab Creek Near Beverly			Columbia River Below Vantage		
	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.
CFS 10^3	0.37	1.81	4.57	0.6	4.47	19.9	0.021	0.041	0.081	54	149	419
Water °F	32.0	42.8	66.7	32.0	46.3	67.3	32.0	56.3	84.7	36.8	50.6	68.7
Dis. Oxy.	9.1	10.4	13.9	9.2	12.0	14.6	7.6	10.9	14.5	9.6	12.4	15.8
% Satur.	88	95	115	91	100	115	85	100	117	92	109	144
Car. Di.	0.5	--	4.0	0	--	2.5	0	--	0	0	--	4.0
pH	7.0	7.4	8.4	6.9	7.3	8.6	8.2	8.5	8.9	6.3	7.6	8.9
Total Alk.	21	32	46	11	29	70	187	341	404	53	62	71
HCO_3-	21	32	46	11	28	70	169	298	373	53	62	71
CO_3=	0	0	0	0	0	8	6	42	100	0	0.2	4
Tot. Hard	19	31	49	7	29	70	110	194	240	56	68	94
Car. Hard	19	30	46	7	26	59	110	194	240	53	62	71
N. C. H.	0	1	11	0	4	15	0	0	0	0	5	23
Sulfates	0	2	8	0	2.2	4.5	33	115	220	4	9	21
Color	0	10	30	0	13	50	15	39	125	2	11	22
Turbid.	1	20	78	1	16	80	18	100	440	0	11	30
Iron	0.00	0.11	0.50	0.00	0.02	0.20	0.00	0.12	0.80	0.00	0.08	0.50
Copper	0.000	0.008	0.030	0.000	--	0.010	0.000	0.008	0.040	0.000	0.004	0.030
Zinc	0.0	--	0.05		0.0*		0.0	0.0	0.0	0.0	0.0	0.0
Lead	0.0	0.0	0.0		0.0*		0.0	0.0	0.0	0.0	0.0	0.0
Aluminum	0.00	0.18	1.3	0.00	0.02	0.09	0.00	0.03	0.5	0.00	0.02	0.20
Calcium	0.5	18.0	60	0.5	7.2	41	19	38	95	10.0	19	26.4
Magnes.	0.1	1.2	3.2	0.1	1.1	4.6	0.1	8.3	20.0	0.3	3.0	6.0
Sodium	0.0	2.6	11.5	1.0	2.0	4.0	19	94	135	0.5	4.0	20
Potass.	0.2	1.6	7	0.9	1.6	3.0	3.9	16.9	50	0.6	1.3	2.6
Mangan.	0.00	0.00	0.00		0.000*		0.00	0.00	0.00	0.00	0.00	0.00

Table 23 Cont'd

	Yakima River Above Thorp			Wenatchee River Near Mouth			Crab Creek Near Beverly			Columbia River Below Vantage		
	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.
Silver	0.00	0.00	0.00		0.000*		0.00	0.00	0.00	0.00	0.00	0.00
Tot. Sol.	17	58	170	19	81	270	575	704	1650	40	107	220
Conduct.	43	71	167	29	47	118	445	979	1180	120	147	219

1 Values Weighted According to flow except for water temp. and dissolved oxygen values which are avg. of monthly averages.

* Single observation

Table 23 - Minimum, Weighted Average and Maximum Observed Constituent Values at Station Indicated [1], 1954-1957

	Columbia River at Rock Island			Nason Creek Near Mouth			Chiwawa River Near Mouth			Wenatchee River Below Plain		
	Min	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.
CFS 10[3]	59	137	445				0.09	0.79	3.51	0.58	3.46	9.51
Water °F	36.0	50.2	64.6	32.0	43.2	62.6	32.0	42.3	57.7	32.0	45.0	62.6
Dis. Oxy.	9.8	12.1	15.2	9.4	11.5	13.4	9.0	11.7	13.7	8.5	11.5	13.7
% Satur.	94	106	123	87	93	123	87	92	100	88	95	101
Car. Di.	0	--	3.0	1.0	--	3.0	0.5	--	3.0	1.0	--	3.0
pH	7.2	7.7	8.3	6.6	7.0	7.7	6.8	7.2	8.0	6.5	7.2	7.7
Total Alk.	50	59	71	8	12	19	9	16	26	9	14	23
HCO_3	50	59	71	8	12	19	9	16	26	9	14	23
CO_3	0	0	0	0	0	0	0		0	0		0
Tot. Hard	54	66	92	7	13	33	8	16	40	8	15	24
Car. Hard	50	59	71	7	11	19	8	15	27	8	14	23
N. C. H.	0	7	22	0	2	15	0	1	14	0	2	9
Sulfates	4	11	21	0.6	3.0	10	0.9	2.2	8.0	1.0	2.5	5.5
Color	0	10	20	0	19	100	0	13	20	1	19	45
Turbid.	1	12	40	2	24	150	2	15	40	2	14	40
Iron		--		0.00	0.06	0.12	0.00	0.01	0.22		--	
Copper		--		0.000	0.001	0.010	0.000	0.13	0.30		--	
Zinc		--			--			--			--	
Lead		--			--			--			--	
Aluminum		--		0.00	0.04	0.20	0.00	0.02	0.06		--	
Calcium		--		1.3	2.3	10	1.5	5.2	9.2		--	
Magnes.		--		0.4	0.7	1.6	0.1	0.8	1.8		--	
Sodium		--		0.3	1.5	3.0	0.5	1.6	3.0		--	
Potass.		--		0.3	1.3	2.4	0.4	1.2	2.0		--	
Mangan.		--						--			--	

Table 23 Cont'd

	Columbia River at Rock Island			Nason Creek Near Mouth			Chiwawa River Near Mouth			Wenatchee River Below Plain		
Silver	Min.	Wt. Avg. --	Max.	Min.	Wt. Avg.	Max.	Min.	Wt. Avg. --	Max.	Min.	Wt. Avg.	Max.
Tot. Sol.	49	94	175	17	72	130	9	102	130	14	70	130
Conduct.	110	131	171	17	27	67	29	35	60	22	29	64

1 Values Weighted According to flow except for water temp. and dissolved oxygen values which are avg. of monthly averages.

* Single observation

Table 23 - Minimum, Weighted Average and Maximum Observed Constituent Values at Station Indicated[1], 1954, 1957

	Wenatchee River Tumwater Canyon			Columbia River Beebe Orchard		
	Min.	Wt. Avg.	Max.	Min.	Wt. Avg.	Max.
CFS 10^3	0.58	3.46	11.5	50	130	387
Water °F	32.0	45.4	62.6	36.5	50.2	64.8
Dis. Oxy.	8.3	11.6	14.0	9.7	12.2	14.9
% Satur.	85	95	100	94	107	128
Car. Di.	0.5	--	3.5	2.0	--	3.0
pH	6.5	7.1	7.9	7.3	7.7	8.3
Total Alk.	10	14	27	54	58	72
HCO_3	10	14	27	54	58	72
CO_3	0	0	0	0	0	0
Tot. Hard	8	15	37	55	63	82
Car. Hard	8	13	28	54	58	72
N. C. H.	0	1	16	0	4	11
Sulfates	0.7	3.4	5.9	6	11	17
Color	1	12	40	0	10	22
Turbid.	1	15	33	2	16	45
Iron		0.05*		0.00	0.02	0.04
Copper		0.000*		0.000	0.009	0.020
Zinc		--			--	
Lead		--			--	
Aluminum		0.24*		0.00	0.03	0.12
Calcium		14.0*		11.0	1.6	24.4
Magnes.		1.0*		1.8	5.7	8.0
Sodium		0.5*		1.5	2.1	3.5
Potass.		1.2*		0.8	1.0	2.0
Mangan.		--			--	

Table 23 Cont'd

Silver	Wenatchee River Tumwater Canyon			Columbia River Beebe Orchard		
	Min.	Wt. Avg. --	Max.	Min.	Wt. Avg. --	Max.
Tot. Sol.	15	85	175	40	100	150
Conduct.	23	33	67	111	126	158

1 Values Weighted According to flow except for water temp. and dissolved oxygen values which are avg. of monthly averages.

* Single observation

TABLE 24 - Monthly Water Temperatures, °F, from Thermograph Records.
Recorded to nearest degree or half degree Fahrenheit.
Average of daily maximum and minimum temperatures.
Period of 1954-1957 or as indicated

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Columbia River at Umatilla (McNary Dam), Oregon												
Avg. 1954	39.1	39.9	42.9	47.9	52.3	55.4	60.2	63.7	63.2	55.5	50.6*	43.9*
" 1955	39.2*	38.9	39.2	45.1	51.7	56.0	59.6	66.1	64.7	57.8	50.9*	--
" 1956	37.8*	33.6	41.2	46.7	52.2*				65.0*	58.7	48.3	41.6
1957	36.3	35.1	42.5									
Min. Recorded	32	32	36	41	46	52	56	62	59	52	42	40
Max. "	42	43	46	52	55	58	63	69	69	65	54	47
Max. Diurnal Var.	2	2	2	2	3	2	2	2	2	2	2	2
Min. " "	0	0	0	0	0	0	0	0	0	0	0	0
Columbia River at Pasco, Washington												
Avg. 1954						55.4	58.0	64.2	64.8*			
" 1955							58.5*	63.9	62.1	58.0		
" 1956				43.9	50.3	54.4	61.6	66.4	65.4	59.5	52.1	45.3
" 1957	39.0	37.9	42.0									
Min. Recorded	34	35	40	42	47	52	54	59	57	54	47	43
Max. "	44	41	44	47	54	58	66	69	68	64	56	48
Max. Diurnal Var.	2	3	2	2	2	6	7	6	4	3	2	3
Min. " "	0	0	0	0	0	0	1	0	0	0	0	0
Columbia River at Rock Island, Washington												
Avg. 1954				42.7*	49.1	53.0	58.6*	61.7	61.0	55.1*	51.2	45.1
" 1955	41.0*	38.4*	37.2	41.3	47.5	53.2	56.8	62.0	61.2	58.1	49.4*	43.3*
" 1956	38.8	35.0	37.5	41.6	49.4	53.5*	58.4	63.2	63.0	59.3	52.5	45.2
" 1957	39.8	36.1	38.0									
Min. Recorded	34	34	35	38	44	49	54	60	57	53	46	40
Max. "	43	40	40	47	53	56	62	65	64	62	56	49
Max. Diurnal Var.	2	2	2	2	1	1	2	2	2	2	2	1
Min. " "	0	0	0	0	0	0	0	0	0	0	0	0

Table 24 Cont'd

	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Columbia River Near Grand Coulee Dam												
Avg. 1954						49.8	54.6	58.0*				
" 1955						52.3*	55.2	60.8	61.3	62.2*		
" 1956				39.6*	48.2	52.6*	56.8	61.8	63.0	63.3*		
Min. Recorded				36	45	49	50	57	60	61		
Max. "				46	52	54	60	64	64	64		
Max. Diurnal Var.				2	1	2	2	3	2	2		
Min. " "				0	0	0	0	0	0	0		
Snake River Near Mouth												
Avg. 1954								71.1	66.3			
" 1955						57.1*	66.2	72.4	67.4	57.7*		
" 1956				49.6*	52.5	59.5	72.7	73.2	66.7	58.7*		
Min. Recorded				47	50	54	56	66	57	54		
Max. "				50	56	66	79	77	75	62		
Max. Diurnal Var.				1	2	2	5	4	3	5		
Min. " "				0	0	0	0	1	0	0		
Yakima River Near Richland												
Avg. 1954						62.1	67.3	69.1	65.2*			
" 1955						65.1*	70.5*	70.3	64.2			
Avg. 1956						64.5*	73.1	72.5	65.1	53.7		
Min. Recorded						59	60	62	57	45		
Max. Recorded						71	81	80	75	60		
Max. Duirnal Var.						5	8	9	8	4		
Min. " "						1	1	2	1	1		

U. S. Fish and Wildlife Service Thermograph Data

* Partial Month

Table 24 Cont'd.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wenatchee River at Lake Wenatchee Outlet												
Avg. 1955								60.0	58.8	51.6	42.6	38.0
Avg. 1956	34.6	34.0	34.5	38.1*	42.9	44.6	51.7	57.6				37.9*
" 1957	36.0	34.2	35.5									
Min. Recorded	34.0	33.5	34.0	35.0	37.5	38.0	43.0	46.5	54.0	47.5	40.5	35.5
Max. "	38.0	34.5	37.5	41.5	48.0	51.0	60.0	68.5	66.0	55.5	49.0	40.5
Max. Diurnal Var.	0.5	1.0	1.0	1.5	8.0	8.5	9.0	15.5	5.0	5.5	2.0	1.0
Min. " "	0	0	0	0	0	1.5	1.0	1.0	0.5	0	0	0
Nason Creek Near Mouth												
Avg. 1955								57.2	53.5	43.7	35.1	32.9
" 1956	33.5*	32.3*	35.8	39.6	42.1	44.0	52.8	59.3	54.0*	44.1*	37.0	35.2*
" 1957	32.4	32.2	36.7									
Min. Recorded	32.0	32.0	32.0	35.5	38.0	39.5	43.5	48.5	44.5	36.5	32.0	32.0
Max. "	36.5	32.5	44.0	44.5	47.0	51.5	63.0	68.0	64.5	52.0	42.0	38.0
Max. Diurnal Var.	2.5	0.5	8.0	8.0	8.5	7.5	8.5	11.0	9.0	6.0	5.0	2.5
Min. " "	0	0	0	3.5	2.5	1.5	3.0	4.0	1.0	1.0	0	0
Chiwawa River, 3 Miles Above Mouth												
Avg. 1955								52.6*	50.9*	41.0*	35.2	
" 1956		32.8*	35.5	39.5	40.4	43.6	49.7	54.7	50.5	42.4	36.0	33.3
" 1957	32.1	32.2	35.7									
Min. Recorded	32.0	32.0	32.0	34.5	36.0	39.0	43.5	47.0	44.5	35.0	32.0	32.0
Max. "	34.5	33.0	44.0	46.0	46.0	49.5	57.0	62.0	57.5	49.0	41.0	36.0
Max. Diurnal Var.	2.0	0	7.5	9.0	6.5	5.5	8.0	10.0	9.5	6.5	5.0	2.5
Min. " "	0	0	0	3.0	2.0	1.5	2.0	4.0	1.0	1.0	0	0

Chelan County P.U.D. Thermograph Data

* Partial Month

Table 24 Cont'd.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wenatchee River, 2 Miles Below Dryden												
Avg. 1954[1]						48.0*	51.3*	57.8	56.7			
" 1955						48.21	53.0[2]	60.4*	57.0	47.7	37.4	33.1
" 1956	33.7	32.8	37.1	42.0	43.9	46.7	54.9	61.4	60.5*	47.8	39.0	36.4
" 1957	32.9	32.7	39.1									
Min. Recorded	32.0	32.0	32.0	36.5	40.5	42.5	46.0	53.0	48.0	41.0	32.0	32.0
Max. "	37.0	36.0	47.0	46.5	48.0	53.0	62.0	68.0	68.0	55.0	45.0	39.5
Max. Diurnal Var.	3.0	2.5	6.5	8.0	5.0	5.5	5.5	10.0	8.5	6.0	4.0	3.0
Min. " "	0	0	0.5	1.0	1.0	1.0	1.0	0	1.5	0	0	0
Wenatchee River, 4 Miles above Leavenworth												
Avg. 1955								58.6	56.5			34.9
" 1956	33.8	32.7	35.9	41.8*	44.6*	48.9*		61.0	57.3	49.6	42.5*	36.3
" 1957	33.0	32.2	37.0									
Min. Recorded	32.0	32.0	32.0	39.0	41.5	45.0		54.0	50.0	43.0	32.0	32.0
Max. "	35.5	34.0	44.0	45.5	48.0	54.0		67.0	63.5	54.0	46.0	39.0
Max. Diurnal Var.	1.5	2.0	4.0	5.0	5.0	4.0		6.5	4.0	3.5	2.5	2.5
Min " "	0	0	0	2.0	2.0	1.0		1.5	0	0.5	0	0
Wenatchee River, 2 Miles Below Plain												
Avg. 1955								57.9	55.3*	47.5*	36.1*	33.7
" 1956	32.8*	32.5*	35.4	39.2	42.1	45.3		61.0*	56.3	49.3	41.7	37.2*
" 1957	33.0	32.8	37.3									
Min. Recorded	32.0	32.0	32.0	32.0	39.0	41.5		52.5	48.0	43.5	32.5	32.0
Max. "	37.0	37.0	44.0	43.0	47.5	51.5		68.5	64.0	55.5	46.0	39.5
Max. Diurnal Var.	3.5	4.0	6.5	11.5	5.0	4.5		8.0	8.0	6.5	4.0	3.0
Min. " "	0	0	1.0	3.0	1.5	0.5		3.5	1.0	1.0	0	0

Chelan County P.U.D. Thermograph Data

* Partial Month

1. U.S. Fish & Wildlife Service Thermograph Data at Monitor, 8 Miles below Dryden

Table 25 - Temperature in Lake Wenatchee at

Station 42, °F

Water Depth in Feet

Date	0	10	25	50	75	100	125	150	175	200	225
1955											
July 12	48.0	46.5	46.0	44.4	43.9	43.0	42.7	42.4	42.0	42.0	--
Aug. 9	55.4	55.4	54.0	51.8	50.2	49.1	48.1	47.6	46.8	46.3	46.1
" 25	53.8	53.8	53.6	53.8	50.2	49.6	--	--	--	--	--
Sept. 7	59.4	59.4	58.0	52.6	49.2	46.6	46.1	--	--	--	--
" 21	56.1	56.0	55.8	55.4	55.2	51.2	48.2	47.3	46.9	46.4	--
Oct. 23	51.8	51.5	51.5	51.0	50.2	50.1	48.4	46.4	46.2	45.9	45.4
1956											
April	Ice on lake until about April 20th.										
May 19	43.0	42.1	41.8	41.1	40.8	40.6	40.6	40.6	40.6	40.6	40.6
June 20	43.5	43.5	43.0	42.6	42.6	42.1	42.1	42.3	--	--	--
July 5	47.8	47.2	46.0	45.4	45.1	44.8	44.4	44.1	43.8	43.2	43.2
" 18	53.4	51.2	48.6	46.8	46.2	46.0	45.0	44.8	44.1	44.1	44.1
Aug. 1	50.4	50.4	50.0	49.3	48.8	48.8	48.7	48.0	--	--	--
" 17	59.8	58.4	57.4	56.1	52.3	49.6	48.0	47.7	46.8	46.4	46.6
" 29	57.0	56.5	55.5	54.2	51.5	49.0	47.8	--	--	--	--
Sept. 12	58.1	58.1	55.4	53.2	50.5	44.0	43.9	43.2	43.0	43.0	43.1
" 25	56.7	56.7	56.5	54.8	51.1	47.6	45.6	45.5	--	--	--
Oct. 10	54.8	54.6	54.0	52.5	51.8	49.1	45.6	45.1	45.0	44.9	--
" 24	50.0	49.8	49.8	49.1	48.4	47.0	45.5	45.1	44.8	44.4	44.0
Nov. 6	47.1	47.1	47.0	47.0	46.6	46.3	45.0	44.6	44.4	44.0	--
" 21	44.6	44.6	44.5	44.4	44.4	44.1	43.8	43.4	43.2	42.8	--
Dec. 18	41.8	41.8	41.7	41.6	41.2	40.8	40.4	40.2	40.0	40.0	40.0
1957											
Jan. 16	Lake almost completely frozen over										
Feb. 13	Lake completely frozen over.										

variations. Average temperatures listed in tables 6-20 are averages of water temperatures taken at the time of sample collection. Table 25 (page 90) lists the water temperatures with depth observed in Lake Wenatchee on the sampling dates shown in the table. Ice and snow prevented lake sampling during the winter months and high winds frequently made lake sampling difficult or impracticable. Table 28 (page 95) lists the thermograph stations established in the Wenatchee River Basin by the Chelan County P.U.D. and by the U. S. Fish and Wildlife Service.

Air temperatures affect the water quality and the amount of flow in these snow-fed streams. Air temperatures from a nearby U. S. Weather Bureau station (20) are shown in tables 6-20 as mean-monthly temperatures.

ANALYSIS OF DATA

General Discussion

The quality of water at all stations sampled was satisfactory for aquatic life (within limits of quality tests that were made and of known fish tolerance to toxicity) with the exception of summer water temperatures that were above 65° F. in the Snake River, lower Yakima River, Crab Creek and the Columbia River from Pasco to below McNary Dam. It has been demonstrated (25) that the virulence of the indigenous myxobacterium Chondrococcus columnaris greatly increases when water temperatures exceed 65° F. These bacteria cause lesions in fish and have resulted in the destruction of large numbers of fish when water temperatures were above 65° F. With the exception of Crab Creek, the water quality at all stations observed would be satisfactory for public water supply if the supply system incorporated facilities for removal of turbidity, color and bacteria (31).

Dissolved oxygen values were high, usually near or above saturation. All streams were alkaline with the exception of those in the Wenatchee River Basin above Leavenworth where pH values below 7.0 were observed for a portion of the year. Carbon dioxide and ammonia values were low and usually insignificant in magnitude. The lower Yakima River, Snake River and Crab Creek have relatively high constituent values for alkalinity, hardness and sulfates.

Analyses for zinc, lead, silver and manganese were made only in the period of June 1954 to May 1955. These elements were not found in any of the samples tested. Traces of copper and aluminum were found at all sampling stations. Sodium values were high in Crab Creek (up to 135 p.p.m.) and relatively high in the Snake River (up to 38 p.p.m.). A discussion of the significant water quality characteristics of each of the sampling stations follows.

Columbia River at MaNary Dam
Table 6, Figures 7 and 8:

Water quality and flow at this station are influenced by the Sanke and Yakima Rivers tributary 32 and 43 miles upstream respectively. The Snake is a large river and in May, the month of its peak flow, the discharge is greater than half that of the Columbia at the point of confluence. In May, the Yakima River discharge is but 2 percent of that in the Columbia. Peak flow at McNary Dam occurs in June when dissolved constituents, such as those producing hardness and alkalinity, are at a minimum for the year. Turbidity and color would normally be highest in June. However, they were greatest in March during this sampling period because of 1957 construction work in the Snake River for the Ice Harbor Dam. Water temperatures rose from a low of 32° F. in January and February to a high of 69° F. in August and September (see table 24, page 86). The river water was supersaturated with dissolved oxygen from May through September. Carbonate alkalinity was observed from August through October, a period when irrigation return flows were markedly influencing water quality in the Snake and Yakima Rivers. Calcium, magnesium, sulfates, sodium and potassium have their greatest concentration during the period of low-water flow from October to March.

Snake River at Mouth
Table 7, Figures 9 and 10:

Average-monthly water temperatures, dissolved oxygen saturation and carbonate alkalinity (with pH) were greatest during the month of August. Water temperatures of 79° F. (table 24) have been observed in the Snake as daily maximums. The average-monthly August water temperature in the period of 1954-1956 was slightly over 72° F. High dissolved oxygen saturation values (average of 119 percent, maximum of

142 percent) are due to photosynthetic activity of the plankton. Carbonate alkalinity was observed from July through December with the maximum August value of 56 mg/l as $CaCO_3$ occurring during the period of peak irrigation return flow. Soluble mineral matter, as indicated by the conductivity, calcium and magnesium, etc., was greatest in the autumn and winter when the reservoirs were drawn down and when the river flow consisted largely of ground water. High total solids, color and turbidity values in February and March are not normal values for these months. They were caused by work on the Ice Harbor Dam, 8 miles upstream from the point of sampling.

Columbia River at Pasco
Table 8, Figures 11 and 12:

In a warm summer, the average-monthly water temperatures in August and September exceed 65° F. Carbonate alkalinity was observed only during the month of August, a period when carbonate alkalinity (CO_3=) was maximum in the Yakima River which discharges into the Columbia River 5 miles upstream from Pasco. Dissolved oxygen saturation, corrected for elevation and saturation table deficiencies (see discussion on reliability of water quality data), is equal to or greater than 100 percent saturation throughout most of the year. Maximum color, turbidity and total solids were observed in the spring when the snow-melt at lower elevation tions was proceeding most rapidly. Ionized dissolved substances, as measured by conductivity, are least during June, the period of maximum runoff.

Yakima River at Enterprise
Table 9, Figures 13 and 14:

Yakima River above Thorp
Table 10, Figures 15 and 16:

The Yakima River flow is regulated for irrigation excepting during the spring runoff. Marked changes in water quality occur as the river passes through the irrigated areas and receives large quantities of return flow. During the summer, the majority of water in the lower river is composed of return flows. In July and August, water temperatures at Richland have exceeded 80° F. At Thorp, the Yakima River is a typical cool, clean, slightly alkaline, low-dissolved solids stream while at Enterprise, 153 river miles downstream, the river is warm, alkaline and relatively high in dissolved organic and inorganic solids. Table 26 is a comparison of average values for typical constituents at Thorp and Enterprise for the month of August (heavy irrigation return flows). Dissolved oxygen concentrations are high at Enterprise despite the volume of organic wastes discharged into the Yakima River from municipalities, industry and from agriculture. Dissolved oxygen values during the hours of darkness were 2-3 p.p.m. less than during daylight hours but they did not drop below 6 p.p.m. at Enterprise (26).

Table 26.--Comparison of Yakima River water quality, average values for August

Constituent	Near Thorp	Enterprise	Percent increase
Temperature	56.4	71.1	26
pH	7.5	8.5	-
Total alkalinity	27	141	420
Carb. alkalinity	0	16	-
Total hardness	26	116	350
Sulfates	1	22	2100
Color	8	12	50
Turbidity	7	16	130
Calcium	7.4	28	280
Magnesium	1.2	3.4	180
Sodium	1.4	22.7	1520
Potassium	2.2	5.1	130
Total solids	42	208	390
Conductivity	51	311	510

Wenatchee River near Mouth
Table 11, Figures 17 and 18:

Water temperatures have risen above 65° F. for 5- or 6-day periods during August and September. However, the night temperatures have dropped well below 65° F. on these occasions. This river, even at the mouth, is of high quality. The water is normally clear, slightly alkaline and saturated with oxygen. Turbidity, total solids and color are high only during the period of spring runoff. In contrast with the Yakima and Snake Rivers, the Wenatchee River has but 0.36 of the dissolved material that is in the Columbia River at their point of confluence (using average yearly constituent values).

Crab Creek near Mouth
Table 12, Figures 19 and 20:

The flow in Crab Creek is low and

subject to fluctuation from irrigation demands and from the discharge of surplus irrigation water. Water temperatures up to 84.7° F. have been observed. Crab Creek water is very alkaline, hard, highly turbid, colored and it is extremely high in dissolved substances in comparison with other Washington streams. Because of its small flow, it has no appreciable effect on Columbia River water quality other than along the east bank below the point of confluence. During daylight hours, the creek is usually supersaturated with oxygen. No dissolved oxygen determinations were made during the early morning hours of darkness. Some high water quality values observed were: pH, 8.9; total alkalinity, 404; carbonate alkalinity, 100; total hardness, 240; sulfates, 220; color, 125; turbidity, 440; sodium, 135; potassium, 50; total solids, 1650; and conductivity, 1180.

Columbia River below Vantage
Table 13, Figures 21 and 22:

Columbia River at Rock Island Dam
Table 14, Figures 23 and 24:

Water quality in the Columbia River at these two locations is substantially the same. Values at the downstream location (below Vantage) are slightly higher for temperature and some dissolved minerals. Low carbonate alkalinities, not observed at Rock Island, were present below Vantage only during the months of August and September. Water temperatures in the river (away from the shore) never reached 65° F. The water was saturated (corrected) with dissolved oxygen on nearly all observations, usually being supersaturated.

Nason Creek near Mouth
Table 15 and 16, Figures 25 and 26:

This is normally a cool, clear stream of high quality except when riled by road construction or by heavy rainfall or snow melt. Water temperatures for the warmest month (August) average under 60° F. The water is very soft, has a low alkalinity and little plant life as evidenced by oxygen saturation on values that are seldom above 100 percent saturation. Water quality data collected by the U. S. Fish and Wildlife Service in 1940 show no significant change when compared with 1955-57 data.

Chiwawa River near Mouth
Table 17, Figures 27 and 28:

Wenatchee River below Plain
Table 18, Figures 29 and 30:

Wenatchee River in Tumwater Canyon
Table 19, Figures 31 and 32:

Water quality at these three locations is substantially the same. The water is normally cool, clear, low in dissolved mineral matter and saturated with oxygen. pH values do not exceed 8.0; total alkalinity and total hardness are less than 27 and 40 mg/1 as $CaCO_3$ respectively; 75 percent of the time, color and turbidity values are less than maximum values prescribed for drinking water of 20 and 10 respectively; and total solids are usually less than 50.

Columbia River at Beebe Orchard Bridge
Table 20, Figures 33 and 34:

Water quality values obtained at this station represent the quality of water entering the study area. Flow characteristics at Beebe are similar to those at Rock Island, below Vantage and at Pasco. The highest observed water temperature was 64.8° F. in September. The river was saturated with oxygen (corrected values) and in June, dissolved oxygen saturation exceeded 130 percent (corrected for altitude and new solubility values). pH was normally under 8.0 and carbonate alkalinity was not found on any of the 18 sampling periods. Bicarbonate alkalinity averaged about 57 mg/1 at $CaCO_3$ excepting during the period of low flow in March when it rose to a maximum of 72. Total hardness averaged 60 mg/1 as $CaCO_3$ except in March when it rose to 82. Turbidity and color were significant only during the period of high runoff in May. The high turbidity value of 45 and color of 17 observed in March 1957 were not normal for this time of year. These high values were apparently caused by unseasonable rainfall in the area as March of 1957 was an exceptionally wet month (20). Total solids averaged less than 100 mg/1. In summary, the Columbia River, as it enters the survey area, is a cool, moderately, soft, low-alkalinity stream with no quality characteristics making it unsuitable for aquatic life.

Lake Wenatchee
Tables 21 and 22:

Table 21 (page 70) gives the water quality constituents observed with depth by the University of Washington from June 1955 through February 1957. Table 22 (page 76) gives the constituent values observed with depth by the U. S. Fish and Wildlife Service in September, October and November of 1939. The U. S. Fish and Wildlife Service and the University data compare very closely. Dissolved oxygen saturation values have not been corrected for altitude and the new solubility values. Therefore, each saturation value should be increased by about 9 percent, making most of the shallow samples saturated with dissolved oxygen.

Strong winds blowing over the lake tend to keep the water well-mixed with depth. The only significant quality change with depth is that of temperature. Stratification, as determined by temperature measurements, occurred only in the late summer and autumn. (See section following on temperature observations.) Lake Wenatchee is a typical oligothrophic lake that is low in dissolved mineral matter, has a continuous abundance of dissolved oxygen and has cold water in its greater depths throughout the year.

The hydrogen-ion concentration (pH) is less than 7.0 (acidic) most of the year. Alkalinity was all bicarbonate (HCO_3-) and never exceeded 16 mg/l as $CaCO_3$. Both carbonate and non-carbonate hardness were observed with carbonate predominating. Total hardness was usually less than 15 mg/l as $CaCO_3$. The water is clear, its color exceeding 10 only once and its turbidity was usually less than 10. Total solids were normally under 50 mg/l. Table 27 summarizes tables 21 and 22 by listing the minimum, average and maximum constituent values observed at different depths throughout the sampling period.

WATER TEMPERATURES

Tables 24 and 25 (pages 86 and 90) present water temperature data in the survey area. Table 24 lists average-monthly water temperatures computed from thermograph records of the U. S. Fish and Wildlife Service and of the Chelan County P.U.D. The average temperature is taken as the average of the daily maximum and minimum temperatures. Thermographs at Pasco, below Grand Coulee Dam, the mouth of the Snake River and the mouth of the Yakima River are operated for only a portion of each year. Diurnal temperature variations (as shown

Table 27.--Lake Wenatchee, minimum, average and maximum constituent values with depth in milligrams per liter. June 1955 - February 1957.

Depth	Less than 15 feet			15 - 75 feet			75 - 125 feet			Over 125 feet		
Samples	25			17			5			15		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Water °F.	32.4	48.5	59.4	40.8	48.9	55.5	42.1	45.3	48.4	40.4	44.7	47.4
Dissolved oxygen	9.3	10.4	13.0	9.3	10.3	13.0	9.2	10.4	11.4	8.7	10.3	14.0
Percent saturation	77	88	102	78	83	101	78	86	90	73	86	108
Carbon dioxide	0.5	1.7	6.5	1	2.0	3.5	1.5	1.9	2.0	1	2.1	5
pH	6.3	6.9	7.6	6.3	6.9	7.5	6.6	6.7	6.95	6.6	6.8	7.3
Total alkalinity	8	11	17	8	10	14	9	9	10	8	10	15
Total hardness	6	12	24	7	11	26	6	12	26	6	12	28
Carbonate hardness	6	9	16	7	9	14	6	8	9.5	6	10	15
N. C. H.	0	2	12	0	2	14	0	4	17	0	2	13
Sulfates	1.0	1.9	3.1	1.2	2.4	5	1.7	2.6	4	1.0	2.2	5.2
Color	0	6	20	0	5	20	3	5	9	2	7	20
Turbidity	2	5	20	2	7	21	2	4	5	2	7	19
Iron	0.00	0.04	0.16	-	-	-	-	-	-	-	-	0.03
Copper	0.00	0.01	0.04	-	-	-	-	-	-	-	-	0.00
Aluminum	0.00	0.03	0.15	-	-	-	-	-	-	-	-	0.00*
Calcium	0.8	3.5	12	-	-	-	-	-	-	-	-	0.05*
Magnesium	0.2	0.8	1.6	-	-	-	-	-	-	-	-	0.08*
Sodium	0.3	1.1	1.5	-	-	-	-	-	-	-	-	2.0 *
Potassium	0.1	1.0	2.0	-	-	-	-	-	-	-	-	1.0 *
Solids	10	35	87	6	37	90	10	33	46	9	35	51
Conductivity 25°	19	27	45	19	26	27.6	20.5	23	25	19	22	27

* Single observation - Ca and Mg values appear in error.

Table 28 - Thermograph Stations in the Wenatchee River Basin*

1 - 150' downstream from U.S.G.S. gaging station at Lake Wenatchee outlet.

2 - Nason Creek - on bridge to Lake Wenatchee State Park.

3 - Chiwawa River - 200' upstream from highway bridge.

4 - Wenatchee River - 2 1/4 miles below Plain bridge.

5 - Wenatchee River - at highway bridge above Tumwater Canyon.

6 - Wenatchee River - at water intake to hatchery about 2 miles above Leavenworth.

7 - Icicle Creek - at County Highway bridge near hatchery about 1 mile above mouth.

8 - Wenatchee River - at Peshastin Bridge.

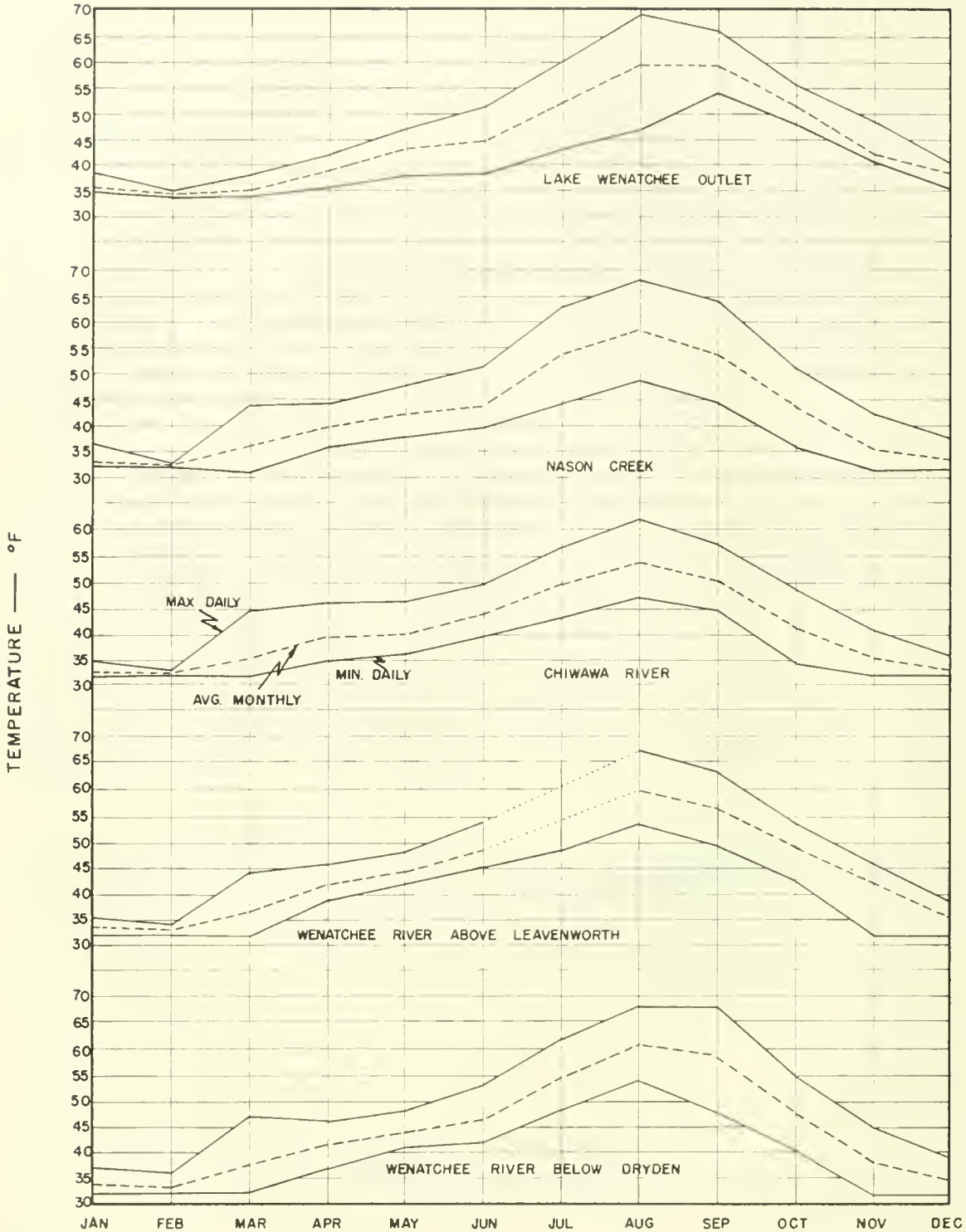
9 - Wenatchee River - at Dryden Bridge. (Middle pier) (Above Dryden dry stretch, where most of water now diverted for power)

#10 - Wenatchee River - spare instrument installed at Dryden Power Plant canal intake.

#11 - Wenatchee River - at Stein's Hill, about 2 miles above Cashmere.

#12 - Wenatchee River - at Monitor Bridge on Wenatchee River. (Summer operation only)

* Stations 1-11 established by Chelan County P.U.D. in August, 1955
Station 12 is maintained by the U. S. Fish and Wildlife Service.

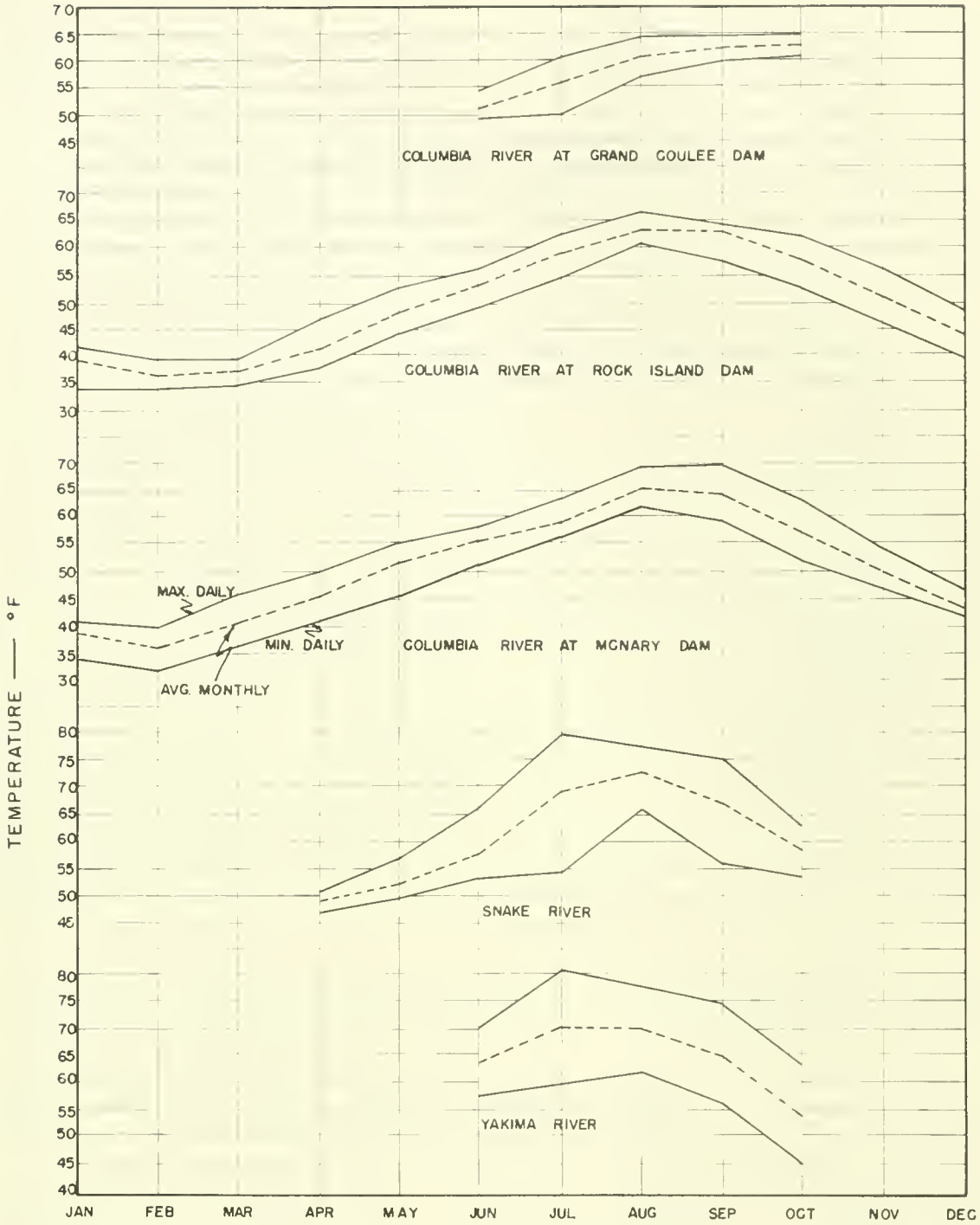


RANGE IN DAILY WATER TEMPERATURES

AUGUST, 1955 — MARCH, 1957

CHELAN P U D. THERMOGRAPH RECORDS

FIG. 35



RANGE IN DAILY WATER TEMPERATURES

JUNE, 1954 —— DECEMBER, 1956

U.S.F. & W.S. THERMOGRAPH RECORDS

FIG. 36

in table 24) are large at some of the thermograph stations during the periods of warm, sunny weather and cool evenings from May through September. Maximum observed diurnal temperature variations during the survey period were: 3° F. in the Columbia River at McNary Dam; 7° F. in the Columbia River at Pasco; 2° F. in the Columbia River at Rock Island; 3° F. in the Columbia River below Grand Coulee Dam; 5° F. in the Snake River; 9° F. in the Yakima River near Richland; 15.5° F. in Lake Wenatchee outlet; 10° F. in the Wenatchee River at Monitor; 11° F. in Nason Creek; 10° F. in the Chiwawa River; 10° F. in the Wenatchee River below Dryden; 6.5° F. in the Wenatchee River above Leavenworth; and 8° F. in the Wenatchee River below Plain.

Figures 35 and 36 illustrate the wide range between the minimum and maximum daily temperatures observed in each month of the year during the survey period. For example, the minimum temperature of 36° F. shown on figure 35 for the Chiwawa River during May is the coldest temperature observed in the Chiwawa River during May of 1956. Daily water temperatures in excess of 65° F. were observed at all stations with the exception of the Columbia River below Grand Coulee Dam, Icicle Creek and the Chiwawa River. Average-daily water temperatures in excess of 65° F. persisted for a month or more in the Yakima River near Richland, in the mouth of the Snake River and in the Columbia River at McNary Dam and at Pasco. They approached this value in the Wenatchee River during August 1956.

Figure 37 is a plot of 1956 water temperatures in the Wenatchee River from Lake Wenatchee to Monitor, 5 miles from the river mouth. It shows the moderating effect of Lake Wenatchee on Wenatchee River water temperatures. From September until March, Lake Wenatchee discharges water warmer than that found downstream while from March through August, the lake discharges cooler water than is found downstream. In August, there is a marked temperature rise from the lake outlet to Plain, 9 miles downstream, followed by little temperature change through Tumwater Canyon to below Dryden, a distance of 31 miles. A marked temperature rise again occurs between Dryden and Monitor (a distance of 10 miles) as the river meanders through a flood-plain offering little shading from solar radiation. In May and June, the colder waters of Icicle Creek reduce the river temperature below Leavenworth.

Table 25 (page 90) is a tabulation of water temperatures with depth observed in Lake Wenatchee from July 1955 to December 1956. Figure 38 is a plot of these temperatures at selected depths during 1956. Maximum temperatures occur in August or September. Vertical currents, set in motion by wind action, warm the entire lake during the spring and summer. Temperature measurements were not made in the winter when the lake was frozen because of the difficulty and danger in getting over the snow-covered ice. In the winter, it is likely that the upper 10-25 feet are at 32° F. and that the deeper water is at the temperature of maximum density, 4° C. or 39.2° F. Thermoclines were

Table 29.--Average monthly water temperatures in the Wenatchee River at Monitor, U. S. Fish and Wildlife Service thermograph station, 5 miles from river mouth.

	April	May	June	July	August	September	October
Average 1954	-	-	48.0*	51.3*	57.8	56.7	-
Average 1955	-	-	48.2*	53.0	61.0	59.0	-
Average 1956	44.2	46.2	49.0	56.9	64.9	61.5	51.4*
Minimum recorded	40	44	44	46	53	49	46
Maximum recorded	47	49	52	64	70	69	56
Maximum diurnal variation	6	3	4	5	10	9	4
Minimum diurnal variation	1	0	0	1	1	2	0

* Partial month

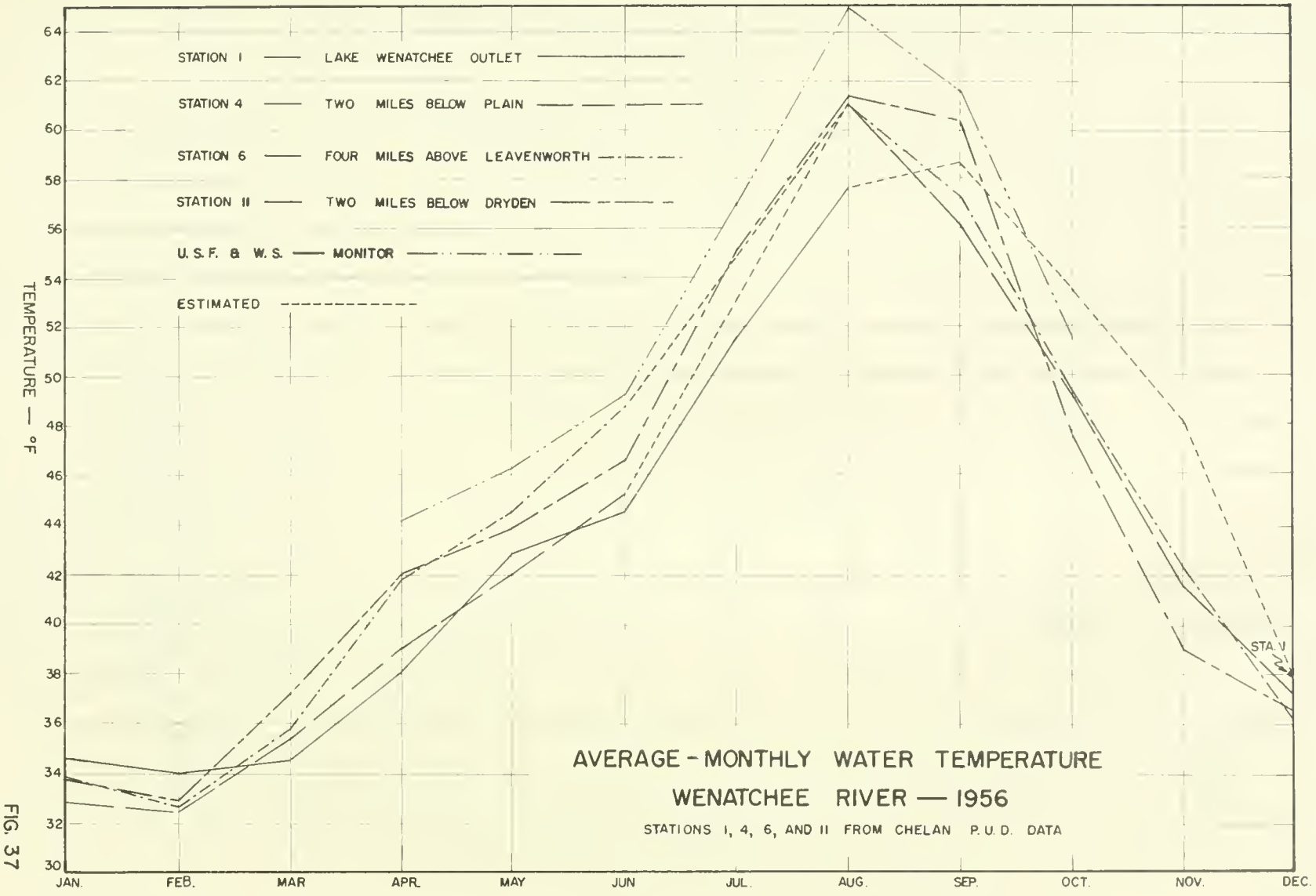
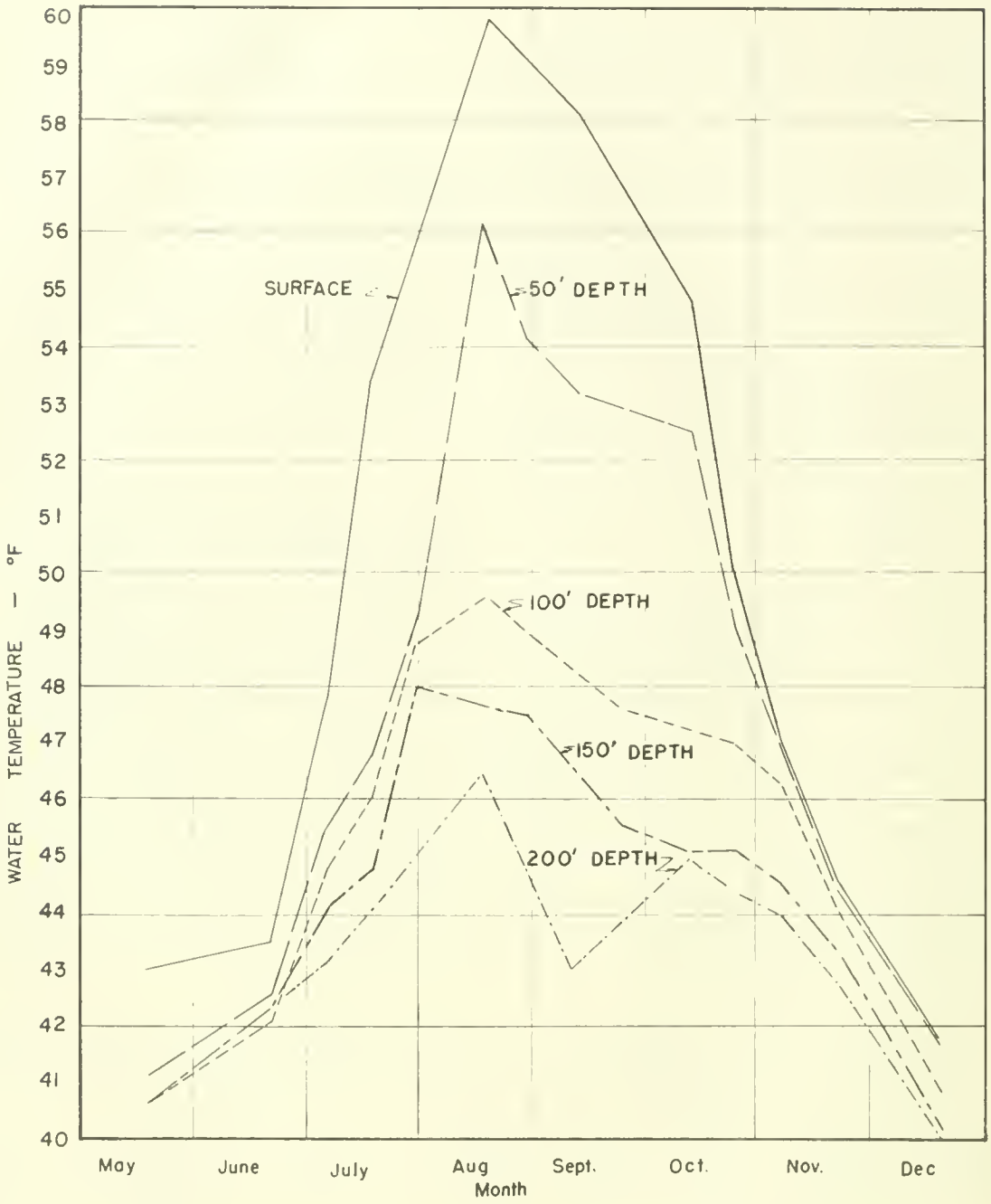

STATION 1 —— LAKE WENATCHEE OUTLET
STATION 4 —— TWO MILES BELOW PLAIN
STATION 6 —— FOUR MILES ABOVE LEAVENWORTH
STATION 11 —— TWO MILES BELOW DRYDEN
U. S. F. & W. S. —— MONITOR
ESTIMATED
TEMPERATURE — °F
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
JAN.
FEB.
MAR
APR.
MAY
JUN
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
STA. V
AVERAGE - MONTHLY WATER TEMPERATURE
WENATCHEE RIVER — 1956
STATIONS 1, 4, 6, AND 11 FROM CHELAN P. U. D. DATA

FIG. 37

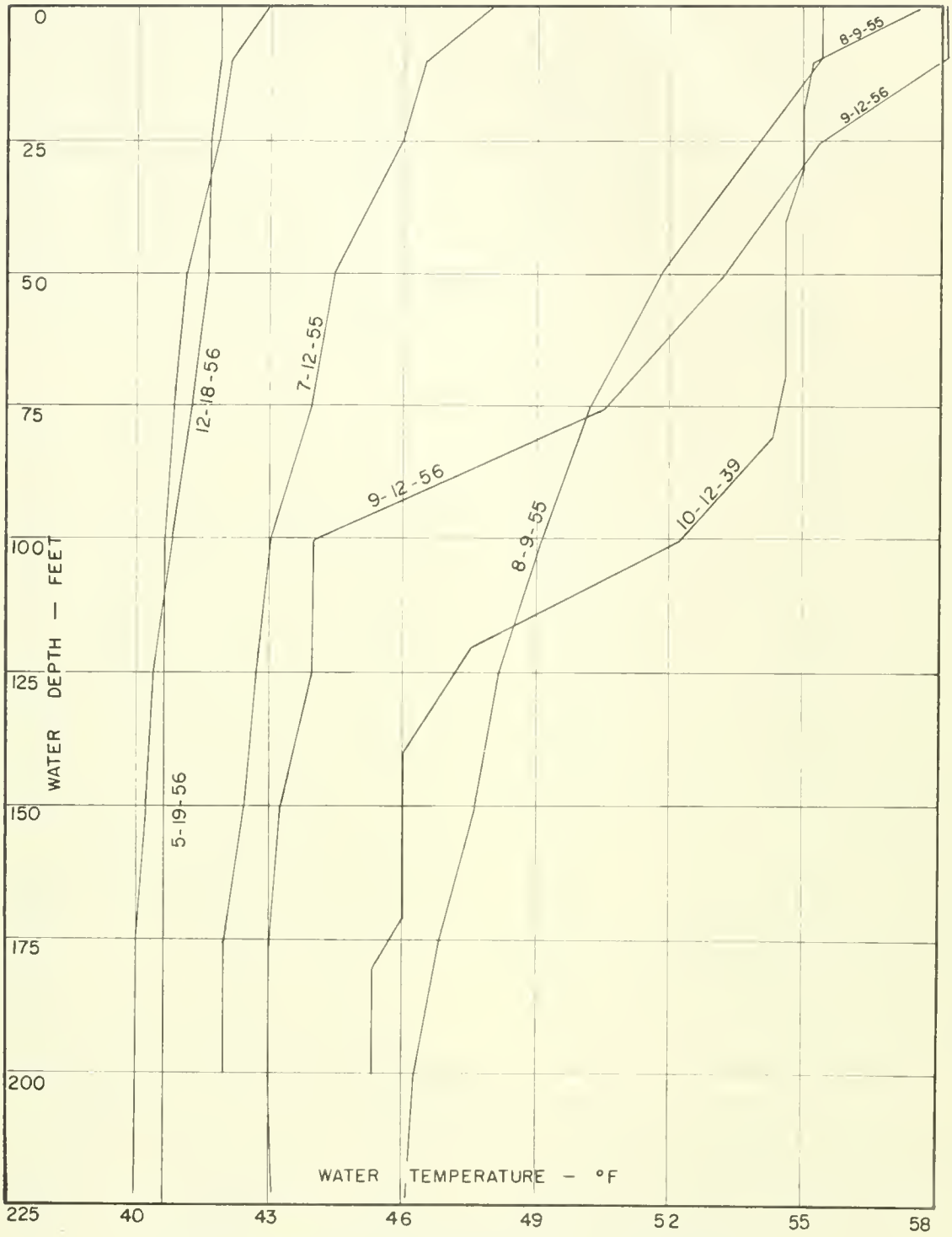


LAKE WENATCHEE WATER TEMPERATURE WITH DEPTH

STATION 42 – May to December 1956

Lake normally frozen over during winter months

FIG 38



TYPICAL WATER TEMPERATURE GRADIENTS

LAKE WENATCHEE, Station 42; 1939, 1955, 1956

FIG. 39

observed in August and September. The depth of the thermocline would vary from 10 to 125 feet, depending upon wind velocities and duration. Below 100 feet in depth, the lake temperature will usually be under 50° F. Figure 39 (page 101) is a plot of typical temperature gradients observed in the spring, summer and autumn. Vertical mixing of the entire lake can be expected in the overturn periods in the spring and autumn.

WATER QUALITY CHANGES FROM UPSTREAM TO DOWNSTREAM LOCATIONS

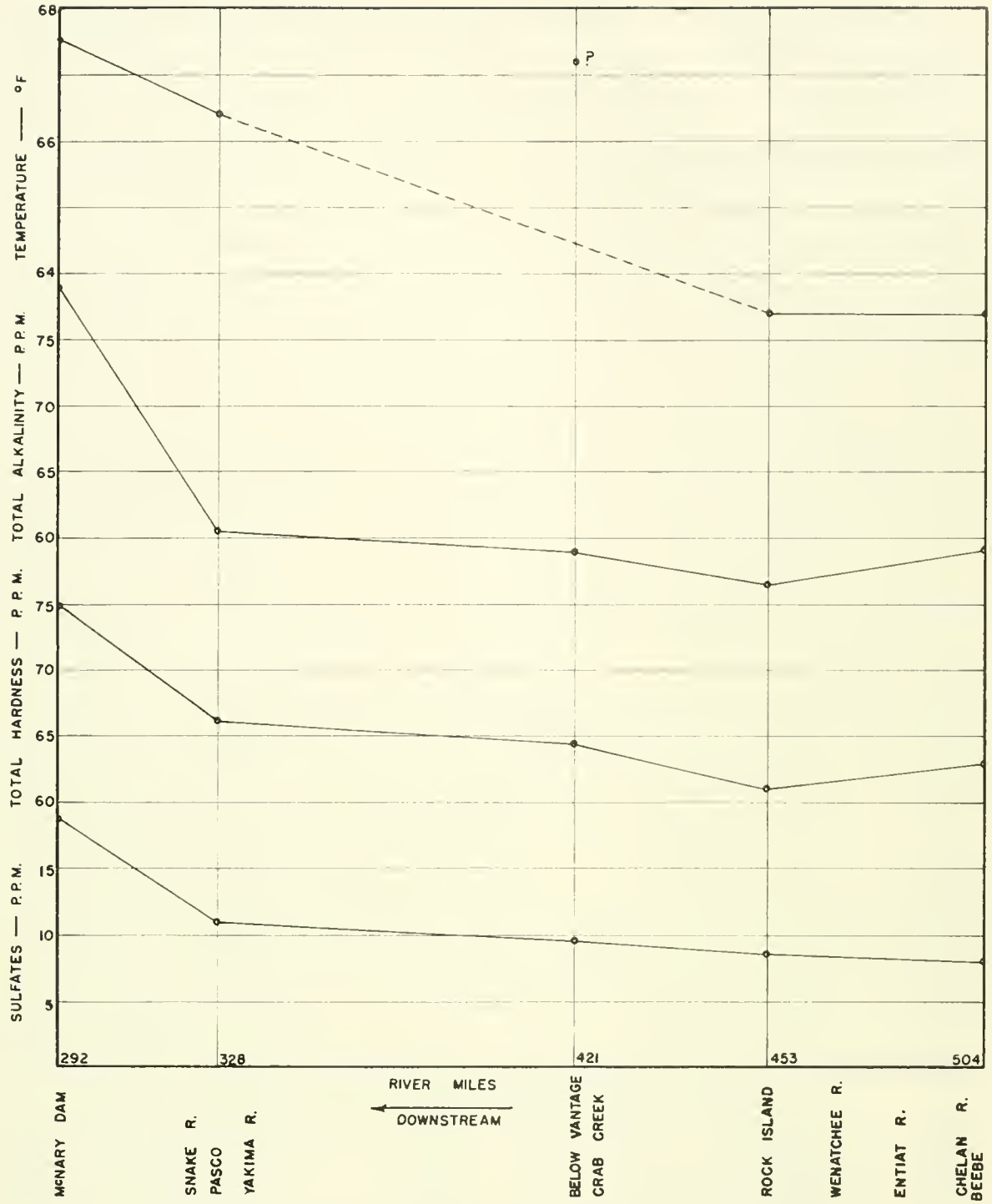
Figures 40 and 41 depict the change in water quality in the Columbia River during the month of August 1956 as the river flows from the upstream station at Beebe Orchard Bridge to the downstream station at McNary Dam, a river distance of 212 miles. In general, the Columbia River water quality changes are small between Beebe and Pasco. The increase in water temperature is the only significant change. Values shown below Vantage for temperature, calcium, sodium and conductivity tend to be high because of the sampling station location. The decrease in alkalinity, hardness and conductivity below Beebe is due to the dilution afforded by the higher-quality water in the Chelan, Entiat and Wenatchee Rivers. An abrupt increase in constituent values occurs between Pasco and McNary Dam, caused by the warm, mineralized Snake River which is tributary to the Columbia River below Pasco. For the period depicted on figures 40 and 41, the water temperature increases from 66.4 to 67.5° F. between Pasco and McNary Dam; total alkalinity from 60.5 to 79 mg/l; total hardness from 66.5 to 75 mg/l; sulfates from 11 to 19 mg/l; calcium from 19.4 to 21.4 mg/l; sodium from 2 to 5 mg/l; total solids from 100 to 140 mg/l; and conductivity from 145 to 176 micromhos per cm.

Figures 42 and 43 (pages 105 and 106) show the change in water quality for the Wenatchee River in August 1956, as it flows from Lake Wenatchee to its confluence with the Columbia River, a distance of 55 river miles. Nearly all quality values show a gradual increase from Lake Wenatchee to the river mouth. Water temperature increases from 57.5 to 64.9° F.; total alkalinity from 9 to 18 mg/l; total hardness from 8 to 16.5 mg/l; calcium from 1.5 to 5.3 mg/l; magnesium from 0.4 to 2 mg/l; sodium from 0.9 to 2 mg/l; total solids from 21 to 58 mg/l; and conductivity from 20 to 49 micromhos per cm. The decrease in sulfates below Lake Wenatchee was caused by dilution of Lake Wenatchee water with lower-sulfate-bearing water in the Chiwawa River and Nason Creek. A reduction in conductivity is shown between the station below Plain and Tumwater Canyon. This reduction is not correct as all other data show a slight increase in conductance between these stations. The apparent reduction was caused by one sample at Plain having an excessive conductance reading which might have been deleted for this monthly summary.

WATER QUALITY CHANGE 1910-11 to 1954-57, Wenatchee River

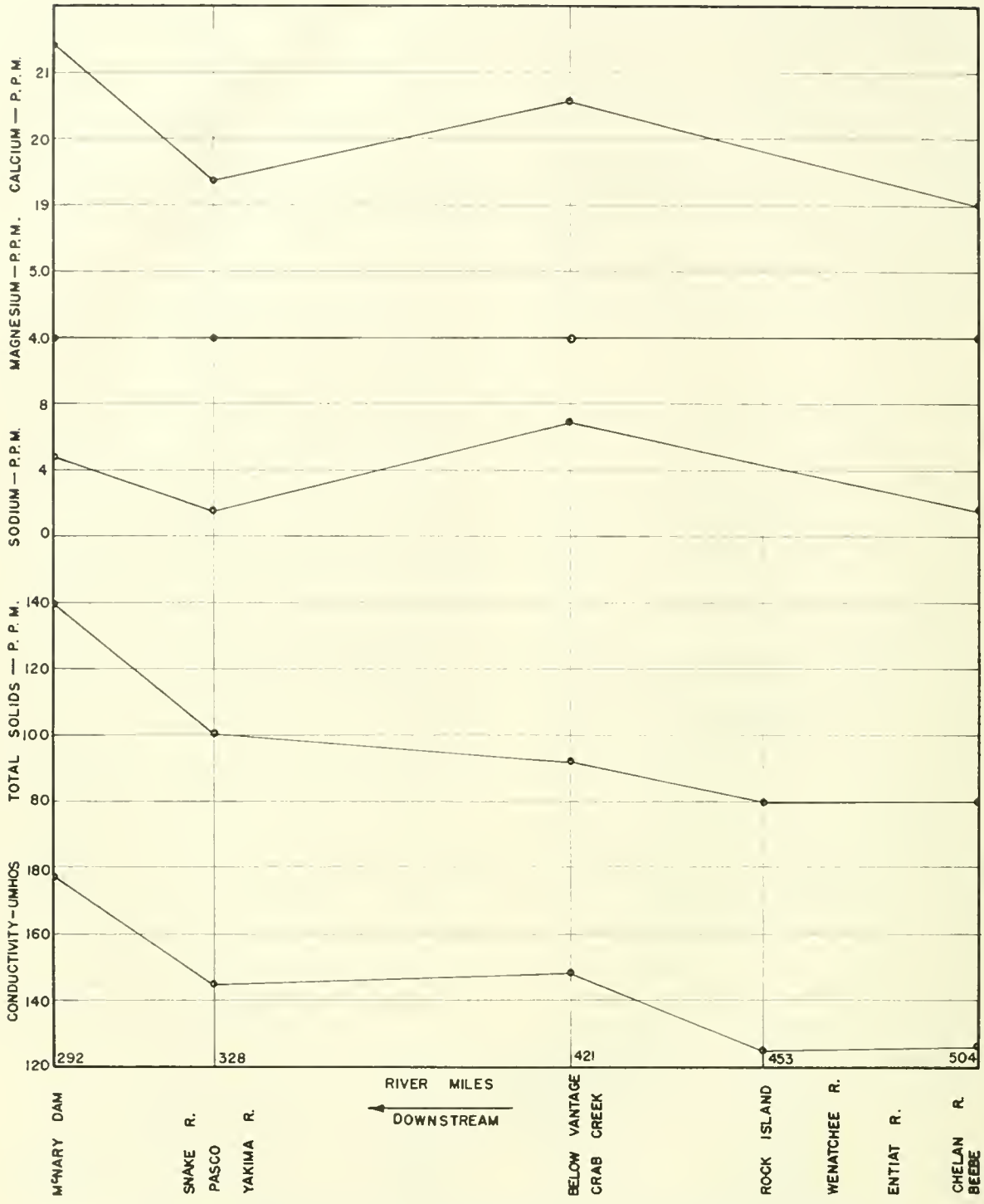
In 1910 and 1911 Walter Van Winkle made a comprehensive study of the chemical quality of Pacific Northwest streams for the U. S. Geological Survey (27). The Wenatchee River at Cashmere was included in this study. Between 1911 and 1954 (beginning of the University of Washington study) very little water quality data were obtained on the Wenatchee River (28). Table 30 (page 107) and figure 44 and 45 (pages 108 and 109) show the constituent values in the Wenatchee River at Cashmere for 1910-11 and at Sleepy Hollow (near the river mouth) for 1954-57. Sleepy Hollow data are comparable with Cashmere data as there are no intervening tributaries and the stations are only 5 miles apart. The data presented can be compared only in a general way since the flow was different for each month and since the sampling frequency was not uniform for both periods.

Between 1910 and 1950 the population in the Wenatchee River watershed increased from 6,200 to 12,000 persons while the irrigated acreage increased from 19,000 to 26,000 acres. Irrigation works were in their maximum period of development around 1910 (7). Impoundments for power and irrigation diversion are minor. Domestic and industrial waste discharge to the river has had no significant effect on the water chemistry. Principal watershed changes during this 45-year period have been in roadbuilding, agriculture and in logging where many coniferous trees have been replaced with deciduous trees. It is then to be anticipated that the water chemistry in 1954-57 would show some increase in



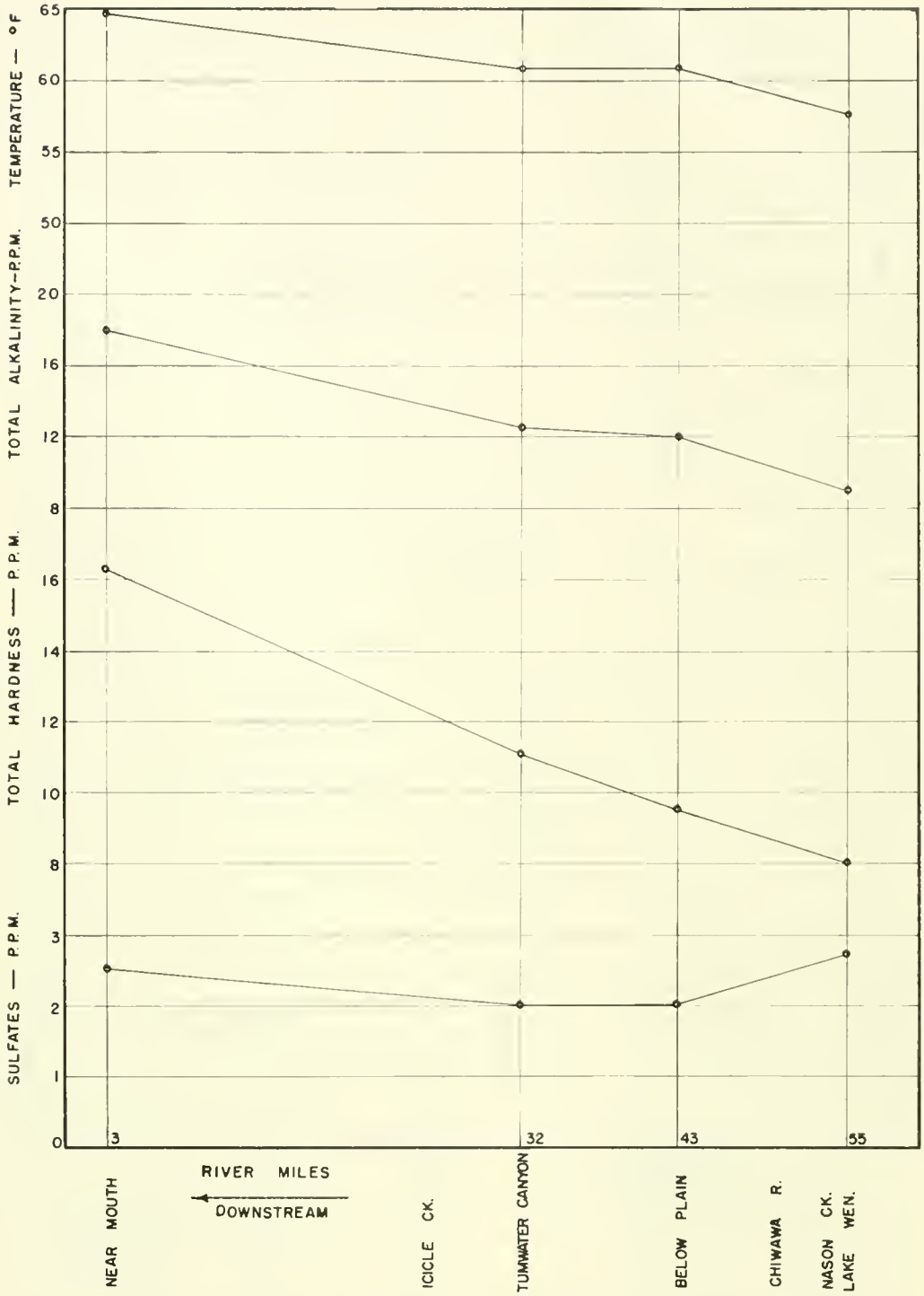
WATER QUALITY CHANGES IN COLUMBIA RIVER
BEEBE ORCHARD BRIDGE TO McNARY DAM
MONTH OF AUGUST, 1956

FIG. 40



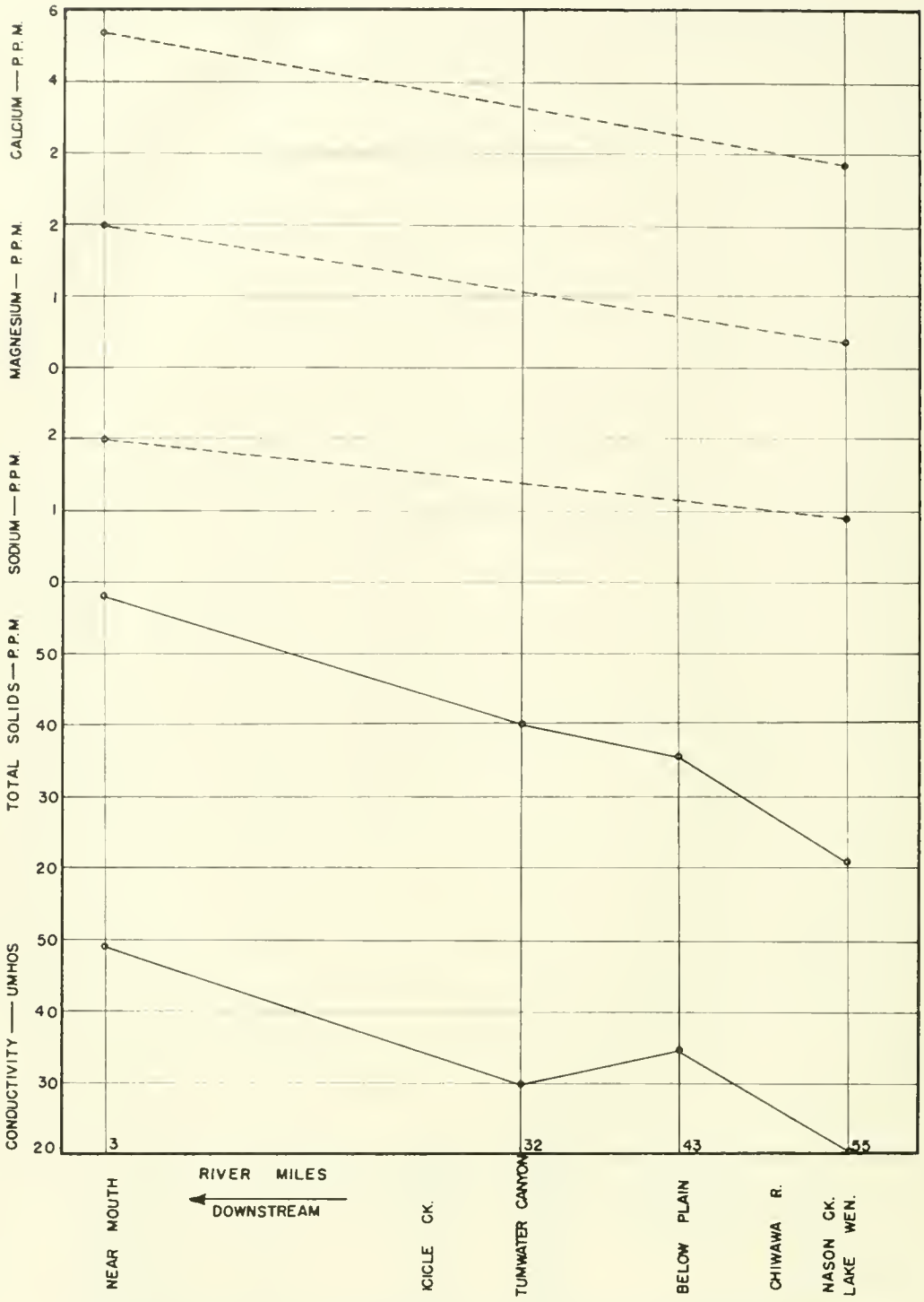
WATER QUALITY CHANGES IN COLUMBIA RIVER
BEEBE ORCHARD BRIDGE TO McNARY DAM
MONTH OF AUGUST, 1956

FIG. 41



WATER QUALITY CHANGES IN WENATCHEE RIVER
LAKE WENATCHEE TO RIVER MOUTH
MONTH OF AUGUST, 1956

FIG. 42



WATER QUALITY CHANGES IN WENATCHEE RIVER
LAKE WENATCHEE TO RIVER MOUTH
MONTH OF AUGUST, 1956

FIG. 43

Table 30 - Water Quality Comparisons, Wenatchee River, 1910-11 with 1954-57. Average monthly values, mg/l.

Wenatchee R. at Cashmere - 1910-11 (U.S.G.S.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Times Sampled	4	3	2	3	3	3	3	3	3	3	3	3
Flow x 10^3	1.22	1.43	4.6	7.4	13.0	7.3	4.6	1.7	0.9	2.8	4.0	1.5
Total Alk.	24	42	27	35	16	13	16	21	26	18	15	21
Sulfate	5.4	9.8	5.2	9.0	8.1	7.3	8.6	6.2	5.8	6.9	7.5	8.1
Color	-	-	8	9	7	7	-	-	-	-	-	-
Turbidity	1	2	22	23	18	11	10	9	4	5	4	3
Ca + Mg	7.5	12.8	11.1	10.6	5.9	6.0	5.3	6.6	8.8	6.5	5.8	7.2
Na + K	3.6	7.7	4.8	6.6	4.2	3.1	4.1	3.3	4.3	3.4	3.1	3.2
Total Solids	45	77	93	87	60	46	36	43	46	36	38	41
Iron	0.01	0.17	0.04	0.07	0.01	1	0.02	0.01	0.01	0.03	0.01	T
Total Hardness	22	40	34	32	18	18	16	23	26	19	18	22

Wenatchee River Near Mouth (Univ. of Wash.) 1954-55-56-57

Times Sampled	2	2	3	1	2	3	8	8	6	4	4	3
Flow x 10^3	1.1	1.0	1.1	4.6	11.3	13.3	9.8	2.9	1.0	1.5	2.8	3.3
Total Alk.	33	35	45	40	43	25	14	20	29	28	24	24
Sulfate	3.6	3.9	3.1	4.6	3.1	1.0	1.4	1.7	2.1	3.6	1.2	2.5
Color	10	8	20	48	17	8	9	6	5	7	7	7
Turbidity	9	5	40	80	18	11	5	8	13	10	4	11
Ca + Mg	5.4	-	14.5	-	-	5.8	8.8	25.0	13.7	11.6	2.9	3.0
Na + K	3.3	-	4.1	-	-	3.0	5.0	2.9	3.6	2.4	3.6	3.8
Total Solids	58	76	77	270	115	53	39	49	46	45	45	41
Iron	0.02	-	0.01	-	-	0.02	0.01	0.02	0.03	0.03	0.00	0.00
Total Hardness	34	37	48	48	55	14	14	19	28	28	22	29

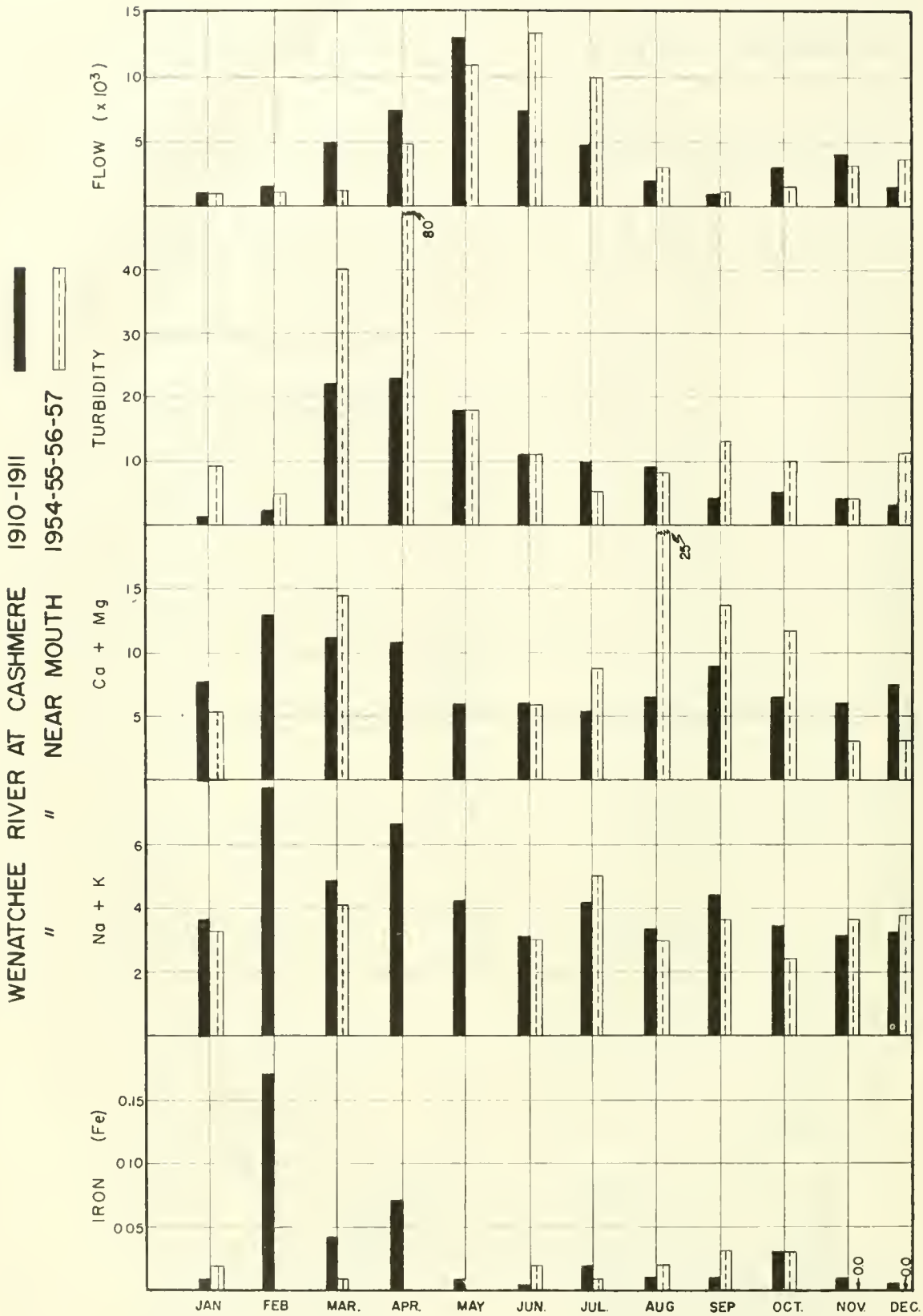

WENATCHEE RIVER AT CASHMERE 1910-1911
" " NEAR MOUTH 1954-55-56-57
FLOW (x 10³)
TURBIDITY
Ca + Mg
Na + K
IRON (Fe)
80
25
JAN
FEB
MAR.
APR.
MAY
JUN.
JUL.
AUG
SEP
OCT.
NOV.
DEC.

FIG. 44

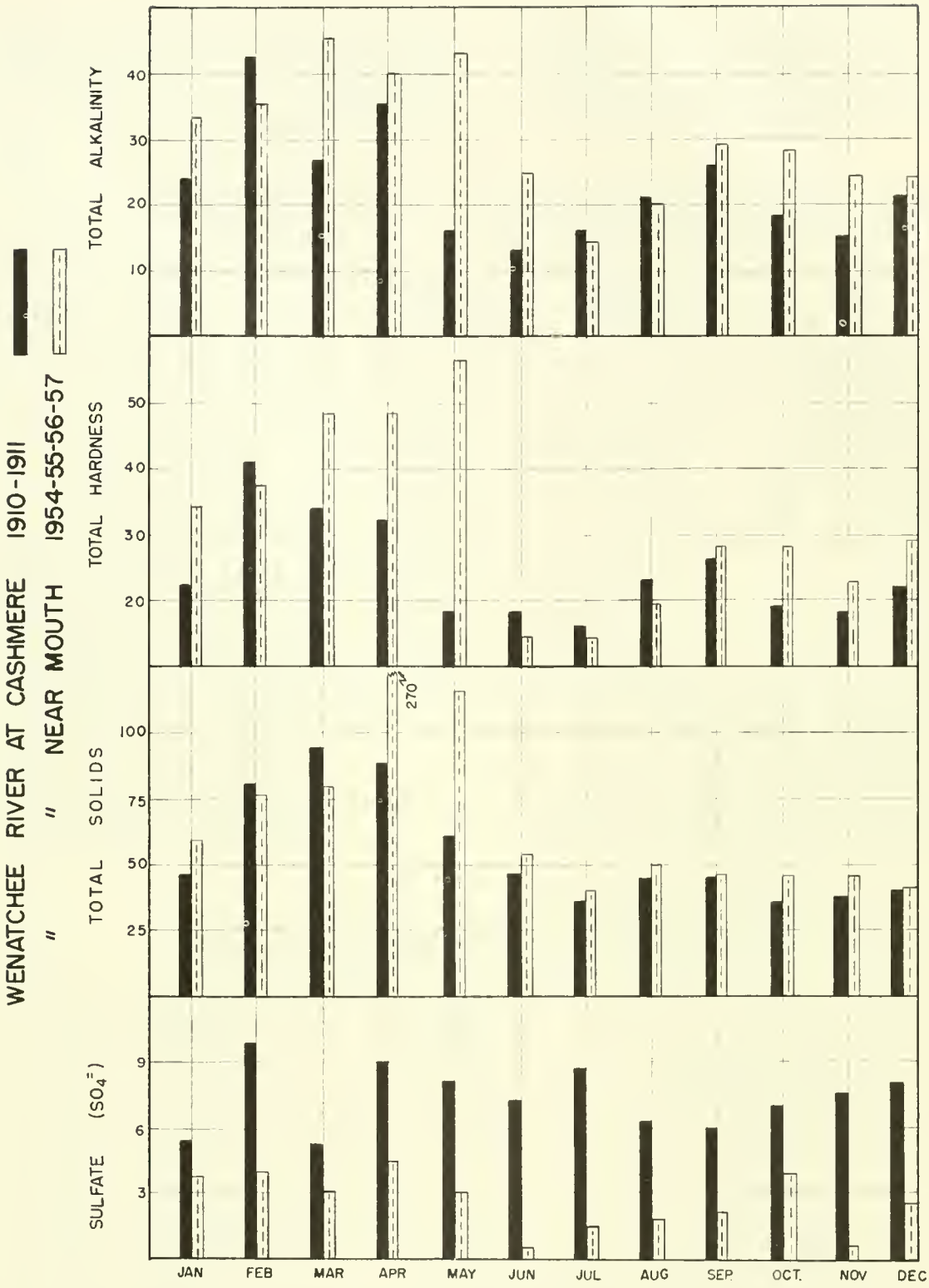

WENATCHEE RIVER AT CASHMERE 1910-1911
" " NEAR MOUTH 1954-55-56-57
TOTAL ALKALINITY
TOTAL HARDNESS
TOTAL SOLIDS
SULFATE ($SO_4^=$)
270
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT.
NOV
DEC

FIG. 45

dissolved substances, turbidity, and color, over that observed in 1910-11 because of soil tilling, removal of natural vegetative covering and because of the addition of deciduous tree leaves that impart color to water.

Table 31.--Weighted-average constituent values in the Wenatchee River, 1910 and 1954-57*.

	At Cashmere 1910-11	Near mouth 1954-57
Flow x 1000 C.F.S.	4.2	4.47
Total alkalinity	21 mg/l	29 mg/l
Total hardness	23 mg/l	29 mg/l
Total solids	50 mg/l	81 mg/l
Sulfate	7.7 mg/l	2.2 mg/l
Ca + Mg 1/	7.0 mg/l	8.3 mg/l
Na + K 1/	3.6 mg/l	3.6 mg/l
Color 2/	8 units	18 units
Turbidity	14 units	16 units
Iron 1/	0.02 mg/l	0.02 mg/l

* Weighted according to flow for average-monthly values shown in table 30.

1/ Less months of February, April and May.

2/ For March, April, May and June only.

Table 31 gives the weighted-average (weighted according to flow) constituent values for these two comparison periods. Values were weighted only for those months where data were available during both periods. Percentage increases were: total alkalinity 43; total hardness 26; total solids 62; calcium plus magnesium 19; sodium plus potassium 0.0; color 125; turbidity 14; and iron 0.0 percent. Sulfate decreased by 71 percent. The reduction in sulfate may be due to a difference in test technique or it may be due to high sulfate values in 1910-11 when rapid leeching was taking place in newly irrigated lands.

Weighted-average constituent values are obtained by multiplying the average-monthly discharge for the times of sampling by the average values of the individual constituents for the month and dividing the year's sum of these products by the total discharge for the year. These weighted-average values are affected by high-flow periods as dissolved constituents are usually low during period of high discharge. Thus, weighted-average constituent values will show lower concentrations than those values obtained by averaging the

Table 32.--Comparison of constituents discharged by Wenatchee River in 1910-11 and 1954-57, 10^3 tons/year.

	At Cashmere 1910-11	Near mouth 1954-57
Total alkalinity	84.78	124.11
Sulfate	31.21	9.57
Ca + Mg 1/	16.16	24.85
Na + K 1/	8.43	10.92
Total solids	237.9	352.1
Iron 1/	0.044	0.043
Total hardness	91.94	127.4

1/ Less months of February, April and May.

individual analyses over a period of a year. The concentration of a dissolved constituent is not inversely proportional to flow on a direct basis. During high-flow periods, the concentration of a constituent per unit volume of flow is less than during low-flow periods.

Perhaps a better method of constituent comparison between time periods could be made on the basis of annual pounds discharged, providing there was not a great difference in the yearly discharge between the time periods. Since the mean annual flows in these two periods under comparison are close, table 32 has been prepared to show the constituents discharged during these two periods in 10^3 tons per year. On this basis, the percent increase in constituents between 1910-11 and 1954-57 was: Total alkalinity 46; calcium plus magnesium 54; sodium plus potassium 29; total solids 48; and total hardness 39 percent. Iron values were substantially the same while sulfate decreased 70 percent. This comparison method gives higher-percentage increases for most of the constituents.

In summary, the activities of man in the Wenatchee River Basin between 1910-11 and 1954-57 has increased the dissolved constituents in the river, on an overall basis, of about 40 percent and the color and turbidity have perhaps doubled.

CHANGE IN DISSOLVED CONSTITUENTS BETWEEN RIVER STATIONS

The specific conductance of a natural water indicates the total concentration of the ionized constituents and it usually correlates closely with the dissolved solids or residue in the water. Determinations for specific conductance are rapid, precise and the sample is not consumed or altered. Table 33 gives the average ratio (of a large number of individual determinations) between dissolved solids and specific conductance for stream stations in the survey area. Values shown for the Wenatchee River are subject to error (solids values too high) since they were computed on the basis of total and not dissolved solids. (University of Washington quality tests were made for total solids and not for dissolved and suspended solids.)

Since individual specific conductance values are subject to less error than are individual solids determination, the ratios of dissolved solids to specific conductance from table 33 were used with specific conductance values from tables 6 to 21 to get

Table 33.--Ratio of dissolved solids to specific conductance [1/]

Stream	No. year	Average dissolved solids P.P.M.	Average specific conductance 25° C.	Ratio
Columbia River at Grand Coulee	3	89.7	148.3	0.60
Columbia River at Maryhill Ferry	3	110.7	176.3	0.63
Yakima River at Cle Elum	1	39	53.4	0.73
Yakima River at Kiona	3	140	212.7	0.66
Snake River at Central Ferry	2	177	274	0.65
Snake River at Kings Hill	2	312	492	0.64
Wenatchee River at Lake Wenatchee [2/]	2	38	23	1.65
Wenatchee River near Wenatchee [2/]	2	52	56	0.93

1/ Using U.S.G.S. data for yearly-weighted-average values.

2/ Using University of Washington data with total solids where turbidity was less than 10.

Table 34- Change in Dissolved Constituents Between River Stations,
Using Specific Conductance as Measure of Dissolved Solids.
See Tables 6 - 21 and 33
Tons-per-Day

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Columbia R. at Beebe	17,900	16,800	13,700	30,000	52,000	69,000	37,600	25,500	14,900	14,000	14,400	12,100
Columbia R. at McNary Dam	39,200	43,300	39,000	71,000	75,000*	114,000	86,500	55,000	42,000	40,200	40,600	33,600
Difference	21,300	26,500	25,300	41,000	23,000	45,000	48,900	29,500	27,100	26,200	26,200	21,500
Snake R. at Mouth 1	16,000	16,800	12,500	32,200	27,700	22,600	14,900	13,900	13,000	19,700	18,500	18,800
Yakima R. at Thorp	0.16	0.084	0.082	--	0.33	0.38	0.33	0.29	0.24	0.15	0.12	0.58
Yakima R. at Enterprise	0.94	1.07	1.23	--	2.28	2.08	1.54	1.22	1.20	1.66	1.44	2.05
Difference	0.78	0.986	1.148	--	1.95	1.70	1.21	0.93	0.96	1.51	1.32	1.47
Wenatchee R. at Lake Wen. 2	--	0.090	--	0.151	1.02	0.51	0.359	0.102	0.050	0.063	0.086	0.312
Wenatchee R. at Sleepy Hollow	0.186	0.195	0.259	1.08	1.53	1.23	0.785	0.335	0.150	0.236	0.350	0.480
Difference	--	0.105	--	0.929	0.51	0.72	0.426	0.233	0.100	0.173	0.264	0.168

1 Snake R. contributes 63 per cent of yearly solids increase in Columbia R. between Beebe and McNary Dam.
2 Using Lake Wenatchee Water Quality
* Value appears low

an approximate measure of total dissolved solids. Using the flow data in the tables, these approximate dissolved solids values were converted into tons-per-day of dissolved solids for the river station to give a comparative measure of the dissolved constituent increase between stations. These values are shown in table 34 which indicates that 63 percent of the yearly solids increase in the Columbia River between Beebe and McNary Dam is contributed by the Snake River and that less than 1 percent is contributed by the Wenatchee and Yakima Rivers. A small portion of the remaining 36 percent is contributed from the Entiat, Chelan, and Walla Walla Rivers and Crab Creek, leaving the major portion of this remaining 36 percent solids increase to come from the solution of mineral matter in the stream bed, from surface runoff and from ground water inflow to the stream bed. On the basis of solids discharged to watershed area, the Wenatchee River discharges about twice the tonnage of dissolved solids per unit of watershed area than does the Yakima River. The reason for this apparent anomaly is that most of the Wenatchee watershed contributes flow to the river whereas much of the Yakima watershed contributes very little flow. In the Wenatchee River watershed the annual runoff is 2.9 c.f.s. per square mile while in the Yakima River watershed it is only 0.57 c.f.s. per square mile.

EFFECT OF PROPOSED IMPOUNDMENTS ON FUTURE WATER QUALITY

The reservoirs proposed for this study area on the Columbia and Wenatchee Rivers (see table 1, page 3) are not large in proportion to river flow. Power installations will be of the so-called run-of-river type where the retention period for river water in each reservoir will be from less than one day during flood stage to perhaps a maximum of 6 to 10 days during periods of low stream flow. Average reservoir water depths will be under 50 feet. During periods of low stream flow (August to April) the entire river discharge will pass through the turbines whose intakes are located near the reservoir bottom. Because of the shallowness and large length-to-width ratio in these impoundments, there should be good vertical and horizontal mixing with little stratification. Surface water temperatures near the dam, when all river discharge is going through the turbines, may exceed average reservoir temperatures by 1 to 3° F. In McNary Reservoir, which is similar to the proposed reservoirs, very little stratification was observed (29). Since these hydroelectric facilities will be used for "peaking" 1/, large diurnal fluctuations in downstream flow and fluctuations in reservoir elevation can be expected during the period of low stream flow. The extent of these "peaking" flow and reservoir fluctuations will depend upon the operational characteristics of each installation and upon how much water is released to the installation from upstream impoundments. With the ultimate development of this stretch in the Columbia River (perhaps within the next ten years) there will be a continuous upstream succession of impoundments and diurnal "peaking" effects will be apparent only along the reservoir shorelines. The only effect on water quality from these "peaking" operations will be a tendency to increase water temperatures slightly as water will be impounded during periods of daylight and released during hours of darkness or reduced solar radiation. A considerable portion of this diurnal impoundment increase will be in the shallower reservoir areas.

Maximum reservoir drawdown in these run-of-river power facilities will normally be from 5 to 10 feet. Therefore, unusually high September water temperatures downstream from these dams will not be experienced as they are when the deep Grand Coulee and Merwin reservoirs (5) are drawn down in September. This does not imply that high water temperatures will not be experienced in September at these reservoirs under discussion. The average August water temperature increase through four reservoirs in the Columbia River Basin (5) was 0.9° F. for each 10,000 acres of impoundment area. If this same temperature increase is experienced in the Columbia River after the Wells, Rocky Reach, Wanapum, Priest Rapids, Wenatchee and Ben Franklin Dams are completed, the August 1956 mean water temperatures (highest for the study period) will be

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1/ "Peaking" is the daily storage of water in a reservoir during periods of lower power demand (daylight and early morning hours) that is released through the turbines during daily periods of higher power demand (say from 5:00 to 11:00 P.M.)

increased in the future from 64.9 to 65.1° F. at Monitor on the Wenatchee River; from 63.2 to 64.8° F. at Rock Island and from 66.4 to 71.4° F. at Pasco, both on the Columbia River. Maximum water temperatures may be somewhat less than indicated since the rate of temperature increase will diminish as water temperatures approach the mean air temperature. If these proposed dams (or a portion of them) were to be high dams with large impoundments having a high depth-to-area ratio, the downstream water temperatures would probably be cooled rather than warmed during the summer (as is the case with Lake Roosevelt and Grand Coulee Dam).

Columbia and Wenatchee river water is low in dissolved and suspended organic matter. The areas where water is to be impounded are also low in organic matter (providing the Wenatchee Reservoir site is cleared of timber). Therefore it is expected that decomposition in the lower reservoir levels will be minor and that there will be no appreciable change in dissolved oxygen due to bacterial decomposition of organic matter. Other decomposition products, such as carbon dioxide, ammonia and sulfides should also be insignificant in the reservoirs and downstream water. One to two p.p.m. less dissolved oxygen should be experienced between the Wells Dam and Pasco during the late summer after the dams have been built because of an increase in water temperature and because of reduced aeration. This anticipated drop in dissolved oxygen may be more than compensated for by photosynthetic activity in the new reservoirs. An oxygen reduction of 2 p.p.m. would still leave ample oxygen for aquatic life. These predictions are made with the assumption that future industrial and municipal waste discharges to the river will have low oxygen demands.

A slight increase in the yearly weighted-average dissolved constituent values should be experienced in the Columbia River after the dams are built because of the longer contact time afforded between the water and the mineral matter in the river bed. This increase may be quite appreciable soon after the water is impounded because of its contact with soil that has previously received a minimum of leeching action from rainfall. This increase in dissolved mineral matter should have no harmful effect on aquatic life; it may be beneficial by augmenting the present food supply. Water turbidity during the flood season should be reduced by deposition in the reservoirs. Water color may be reduced through increased bleaching by the sun in the new reservoirs.

SUMMARY

A water quality study has been made in the Wenatchee River Basin and on the Columbia River from Beebe (near Chelan) to McNary Dam for the purpose of ascertaining the effect proposed dam construction will have on water quality and its relation to aquatic life. Six dams are under construction or are proposed for construction in this section of the Columbia River and its tributaries. These will be low-head run-of-river hydroelectric facilities. Fourteen water sampling stations were established in the study area. Water samples were analyzed for the common constituents and for other constituents which might affect aquatic life.

Water quality data were summarized and documented. These data will make it possible to evaluate future water quality data obtained after the dams have been constructed. U. S. Fish and Wildlife Service and Chelan County P.U.D. thermograph records of water temperature have been summarized and analyzed. U. S. Geological Survey quality of water data have been used when applicable. A comparison was made of 1910-11 water quality in the Wenatchee River with that observed in the 1954-57 period.

The Wenatchee River and its tributaries are cool, "clean" waters. They are low in dissolved constituents and are low in suspended matter except during periods of high runoff. The Columbia River between Beebe and Pasco usually has maximum temperatures under 65° F. It is saturated with dissolved oxygen and contains only a moderate amount of dissolved and suspended constituents. Below the Snake River confluence, the Columbia River water quality at McNary Dam shows a marked change from that observed at Pasco. During the summer, the Snake River may raise the Columbia River temperature by 2.5° F. and increase its dissolved constituents by 20+ percent. Water quality data obtained from all stations throughout the year gave no data,

with the exception of temperature, that would indicate the water to be questionable for aquatic life. Average water temperatures in excess of 65° F. may persist for a month or more at McNary Dam, at Pasco and in the lower reaches of the Snake and Yakima Rivers.

The proposed impoundments in this section of the Columbia River Basin should not alter the chemical or physical quality of the water sufficiently to have any harmful effect on aquatic life. Temperature increases during the summer months will be the principal effect these impoundments may have on water quality. Water temperatures in excess of 70° F. should be experienced at McNary Dam for a period of a month or more after the proposed reservoirs are filled. The months of high water temperature will be August and September.

Additional study is needed on the effect that reservoirs have on downstream water temperatures. Existing data relating water quality to aquatic life is voluminous but difficult to apply as the variables in most bio-assays have been limited. These variables are the test animal, water temperature, time and the relative concentration of dissolved mineral matter and dissolved gases. More study is needed on the relationship of these variables with the migration and spawning of anadromous fishes in the Columbia River system.

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